ETSI TS 103 052 V1.1.1 (2011-03)

Technical Specification

Electromagnetic compatibility and Radio spectrum Matters (ERM); Radiated measurement methods and general arrangements for test sites up to 100 GHz

Reference
DTS/ERM-TG27-013

Keywords
radio, testing

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00   Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Introduction

The recent creation of TS 103 051 [i.1] came about because of the demand for information and guidance in the frequency range up to 100 GHz. Whilst TS 103 051 [i.1] covers the expanded measurement uncertainty associated with measurement activities, it became obvious that a companion document was required that deals with the corresponding methods of measurement.

The present document can be considered as complementary to TS 103 051 [i.1] and is based on the previous TR 102 273 [5] series of documents. It is offered as a practical guide to making radiated measurements of electromagnetic fields at frequencies up to 100 GHz. In doing so, it has incorporated the state of the art regarding measurement techniques available to test houses and commercial laboratories.

From an international perspective, measurements for radio testing, both radio parameters and EMC are already required above 1 GHz, notably in the US FCC regulations (40 GHz, ITU-R spurious emissions (300 GHz) and CISPR EMC testing (6 GHz). These extensions to the measurement frequency range necessitate a review and some level of co-ordination to ensure that a common approach to test methods and their associated measurement uncertainty calculations are agreed.

Contrary to the requirement for performing measurements at frequencies up to 100 GHz, the descriptions of traceable validation or the calibration of test sites are weak and lead to larger uncertainties in the measurement results. This document expands the information and makes recommendations for open area test sites, semi-anechoic rooms and anechoic test chambers and their use for making radiated measurements up to 100 GHz.

Measuring receivers i.e. test receivers or spectrum analysers with coaxial inputs are commercially available for frequencies up to about 67 GHz. The frequency range can now be extended by the use of external harmonic mixers. These devices use an EHF local oscillator signal derived from the measuring receiver and applied to the mixing element together with the incoming signal under investigation. The mixing element internally generates harmonics of the LO that mix with the incoming signal thereby creating an output IF signal that is within the range of the measuring receiver. Such devices are waveguide based and have frequency ranges matching the waveguide bands.

The present document is offered as an assistive document to ETSI standard makers. Whilst it remains the responsibility of the individual Technical Bodies to define their own test methodologies, the present document should be considered as a source of what is possible, practical and therefore recommended.

1 Scope

The present document provides information on general arrangements for radiated measurements from 30 MHz to 100 GHz, and guidance on the use of radiation test sites. The present document captures the state of the art regarding radiated measurement techniques, their capabilities and associated arrangements.

Whilst it remains the responsibility of the individual technical bodies to define their own test methodologies, the present document should be considered as a source of what is possible, practical and therefore recommended.

The basic principles of substitution, pre-substitution and field strength measurements are outlined in the present document. The general descriptions and their calibration and validation are included for Open Area Test Sites (OATS), Semi-Anechoic Rooms with conductive ground plane and Fully Anechoic Rooms (FAR).

Equipment and its arrangement when used to perform radiated measurements such as the following are addressed:

- Measuring receiver.
- Test antennas.
- RF cables and waveguides.
- External harmonic mixers.

The extension to the measurement frequency range necessitates some information to the radiated test methods and their associated expanded measurement uncertainty.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

[1] CISPR 16-1-1: "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus".

[2] CISPR 16-1-4: " Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements".

[3] CISPR 16-1-5: "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-5: Radio disturbance and immunity measuring apparatus - Antenna calibration test sites for 30 MHz to 1 000 MHz".

[4] ETSI TR 100 028 (V1.4.1) (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics".

[5] ETSI TR 102 273 (all parts) (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties".

[6] ANSI C63.5 (2006): "American National Standard for Calibration of Antennas Used for Radiated Emission Measurements in Electro Magnetic Interference".

[7] JCGM 100:2008: "Evaluation of measurement data - Guide to the expression of uncertainty in measurement".

[8] CISPR 16-4-2: "Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-2: Uncertainties, statistics and limit modelling - Uncertainty in EMC measurements".

[9] ISO/IEC 17025:2005/Cor 1:2006: "General requirements for the competence of testing and calibration laboratories".

[10] EA-4/16: "EA guidelines on the expression of uncertainty in quantitative testing".

[11] CIRSPR 16-2-3: "Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements".

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TS 103 051: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Expanded measurement uncertainty for the measurement of radiated electromagnetic fields".

[i.2] IEC 60153: "Hollow metallic waveguides".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

antenna: that part of a transmitting or receiving system that is designed to radiate or to receive electromagnetic waves

antenna factor: quantity relating the strength of the field in which the antenna is immersed to the output voltage across the load connected to the antenna.

antenna gain: ratio of the maximum radiation intensity from an (assumed lossless) antenna to the radiation intensity that would be obtained if the same power were radiated isotropically by a similarly lossless antenna

bit error ratio: ratio of the number of bits in error to the total number of bits

calibration: operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

combining network: network allowing the addition of two or more test signals produced by different sources (e.g. for connection to a receiver input)

NOTE: Sources of test signals are normally connected in such a way that the impedance presented to the receiver is 50 Ω. Combining networks are designed so that effects of any intermodulation products and noise produced in the signal generators are negligible.

correction factor: numerical factor by which the uncorrected result of a measurement is multiplied to compensate for an assumed systematic error

confidence level: probability of the accumulated error of a measurement being within the stated range of uncertainty of measurement

directivity: ratio of the maximum radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions (i.e. directivity = antenna gain + losses)

duplex filter: device fitted internally or externally to a transmitter/receiver combination to allow simultaneous transmission and reception with a single antenna connection

error of measurement (absolute): result of a measurement minus the true value of the measurand

error (relative): ratio of an error to the true value

expansion factor: multiplicative factor used to change the confidence level associated with a particular value of a measurement uncertainty

NOTE: The mathematical definition of the expansion factor can be found in clause D.5.6.2.2 of TR 100 028 [4].

extreme test conditions: conditions defined in terms of temperature and supply voltage

NOTE: Tests are normally made with the extremes of temperature and voltage applied simultaneously. The upper and lower temperature limits are specified in the relevant testing standard. The test report states the actual temperatures measured.

error (of a measuring instrument): indication of a measuring instrument minus the (conventional) true value

free field: field (wave or potential) which has a constant ratio between the electric and magnetic field intensities

free space: region free of obstructions and characterized by the constitutive parameters of a vacuum

impedance: measure of the complex resistive and reactive attributes of a component in an alternating current circuit

impedance (wave): complex factor relating the transverse component of the electric field to the transverse component of the magnetic field at every point in any specified plane, for a given mode

influence quantity: quantity which is not the subject of the measurement but which influences the value of the quantity to be measured or the indications of the measuring instrument

intermittent operation: operation where the manufacturer states the maximum time that the equipment is intended to transmit and the necessary standby period before repeating a transmit period

isotropic radiator: hypothetical, lossless antenna having equal radiation intensity in all directions

limited frequency range: limited frequency range is a specified smaller frequency range within the full frequency range over which the measurement is made

NOTE: The details of the calculation of the limited frequency range are normally given in the relevant testing standard.

maximum permissible frequency deviation: maximum value of frequency deviation stated for the relevant channel separation in the relevant testing standard

measuring system: complete set of measuring instruments and other equipment assembled to carry out a specified measurement task

measurement repeatability: closeness of the agreement between the results of successive measurements of the same measurand carried out subject to all the following conditions:

- the same method of measurement;
- the same observer;
- the same measuring instrument;
- the same location;
- the same conditions of use;

- repetition over a short period of time.

measurement reproducibility: closeness of agreement between the results of measurements of the same measurand, where the individual measurements are carried out changing conditions such as:

- method of measurement;
- observer;
- measuring instrument;
- location;
- conditions of use;
- time.

measurement result: set of quantity values being attributed to a measurand together with any other available relevant information

measurand: quantity intended to be measured

metrological traceability: property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

noise gradient of EUT: function characterizing the relationship between the RF input signal level and the performance of the EUT

EXAMPLE: The SINAD of the AF output signal.

nominal frequency: one of the channel frequencies on which the equipment is designed to operate

nominal mains voltage: declared voltage or any of the declared voltages for which the equipment was designed

normal test conditions: conditions defined in terms of temperature, humidity and supply voltage stated in the relevant testing standard

normal deviation: frequency deviation for analogue signals which is equal to 12 % of the channel separation

polarization: for an electromagnetic wave, the figure traced as a function of time by the extremity of the electric vector at a fixed point in space

quantity (measurable): attribute of a phenomenon or a body which may be distinguished qualitatively and determined quantitatively

rated audio output power: maximum audio output power under normal test conditions, and at standard test modulations, as declared by the manufacturer

rated radio frequency output power: maximum carrier power under normal test conditions, as declared by the manufacturer

shielded enclosure: structure that protects its interior from the effects of an exterior electric or magnetic field, or conversely, protects the surrounding environment from the effect of an interior electric or magnetic field

SINAD sensitivity: minimum standard modulated carrier-signal input required to produce a specified SINAD ratio at the receiver output

stochastic (random) variable: variable whose value is not exactly known, but is characterized by a distribution or probability function, or a mean value and a standard deviation

EXAMPLE: A measurand and the related measurement uncertainty.

test fixture: auxiliary means for determination of relative values at different temperatures for establishing a relation to absolute values

test load: 50 Ω substantially non-reactive, non-radiating power attenuator which is capable of safely dissipating the power from the transmitter

test modulation: test modulating signal is a baseband signal which modulates a carrier and is dependent upon the type of EUT and also the measurement to be performed

trigger device: circuit or mechanism to trigger the oscilloscope timebase at the required instant

NOTE: It may control the transmit function or inversely receive an appropriate command from the transmitter.

uncertainty (of measurement): parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

uncertainty (expanded): quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

wanted signal level: for conducted measurements a level of +6 dBμV emf referred to the receiver input under normal test conditions

NOTE 1: Under *extreme test conditions* the value is +12 dBμV emf.

NOTE 2: For analogue measurements the wanted signal level has been chosen to be equal to the limit value of the measured usable sensitivity. For bit stream and message measurements the wanted signal has been chosen to be +3 dB above the limit value of measured usable sensitivity.

3.2 Symbols

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

β	$2\pi/\lambda$ (radians/m)
γ	incidence angle with ground plane (°)
λ	wavelength (m)
ϕ_H	phase angle of reflection coefficient (°)
η	120π Ohms - the intrinsic impedance of free space (Ω)
μ	permeability (H/m)
AF_R	antenna factor of the receive antenna (dB/m)
AF_T	antenna factor of the transmit antenna (dB/m)
AF_{TOT}	mutual coupling correction factor (dB)
c	calculated on the basis of given and measured data
C_{cross}	cross correlation coefficient
d	derived from a measuring equipment specification
$D(\theta,\phi)$	directivity of the source
d	distance between dipoles (m)
δ	skin depth (m)
d_1	an antenna or EUT aperture size (m)
d_2	an antenna or EUT aperture size (m)
d_{dir}	path length of the direct signal (m)
d_{refl}	path length of the reflected signal (m)
E	electric field intensity (V/m)
E_{DH}^{max}	calculated maximum electric field strength in the receiving antenna height scan from a half wavelength dipole with 1 pW of radiated power (for horizontal polarization) (μV/m)
E_{DV}^{max}	calculated maximum electric field strength in the receiving antenna height scan from a half wavelength dipole with 1 pW of radiated power (for vertical polarization) (μV/m)
e_{ff}	antenna efficiency factor
ϕ	angle (°)
Δf	bandwidth (Hz)
f	frequency (Hz)
$G(\theta,\phi)$	gain of the source (which is the source directivity multiplied by the antenna efficiency factor)
H	magnetic field intensity (A/m)
I_0	the (assumed constant) current (A)
I_m	the maximum current amplitude

k	$2\pi/\lambda$
k	a factor from Student's t distribution
k	Boltzmann's constant (1,38 x 10-23 Joules/Kelvin)
K	relative dielectric constant
l	the length of the infinitesimal dipole (m)
L	the overall length of the dipole (m)
l	the point on the dipole being considered (m)
m	measured
p	power
$Pe_{(n)}$	probability of error n
$Pp_{(n)}$	probability of position n
P_r	antenna noise power (W)
P_{rec}	power received (W)
P_t	power transmitted (W)
θ	angle (°)
ρ	reflection coefficient
r	rectangular distribution
r	the distance to the field point (m)
ρ_g	reflection coefficient of the generator part of a connection
ρ_l	reflection coefficient of the load part of the connection
R_s	equivalent surface resistance (Ω)
σ	conductivity (S/m)
σ	standard deviation
SNR_{b*}	Signal to noise ratio at a specific BER
SNR_b	Signal to noise ratio per bit
T_A	antenna temperature (Kelvin)
u	U-distribution
U	the expanded uncertainty corresponding to a confidence level of x %: $U = k \times u_c$
V_{direct}	received voltage for cables connected via an adapter (dBμV/m)
V_{site}	received voltage for cables connected to the antennas (dBμV/m)
W_0	radiated power density (W/m^2)

3.3 Abbreviations

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

dB	decibel
emf	electromotive force
ERP	Effective Radiated Power
EUT	Equipment Under Test
FAR	Fully Anechoic Rooms
FSL	Free Space Loss
IF	Intermediate Frequency
LO	Local Oscillator
m	meter
Mu	Measurement uncertainty
NSA	Normalized Site Attenuation
OATS	Open Area Test Site
RF	Radio Frequency
RVC	ReVerberation Chambers
SINAD	Signal Noise And Distortion
VSWR	Voltage Standing Wave Ratio

4 General measurement principles used for radiated measurements

4.1 Substitution method

The substitution method can be used even without proven suitability of the test site since the errors of the test site at certain frequencies are constant and become compensated by the substitution. Accuracy of the substitution predominantly depends on the accuracy of the RF source's indicator and the exact gain specification of the substitution antenna.

NOTE: The term "accuracy" is defined, in relation to the measured value, in clause 4.1.1 of TR 102 273 [5].

4.1.1 Principle of the substitution measurement method

When assessing the radiated power with the substitution method the peak power is evaluated. Due to a vast compensation of the failure impacts of the "comparison test site" the Measurement uncertainty (Mu) can be significantly reduced. Disadvantage of this method is that it causes increased time expenditure when a lot of values have to be determined for a EUT.

On the one hand a substitution test site comprises a suitable "comparison test site" (blue boxes). This site consists of an antenna without factors (1), whereas this antenna shall provide sufficient aperture angle, a height adjustable support (2), an antenna cable (3) as well as an indicator (4) consisting of a measuring receiver or a spectrum analyzer or a power meter.

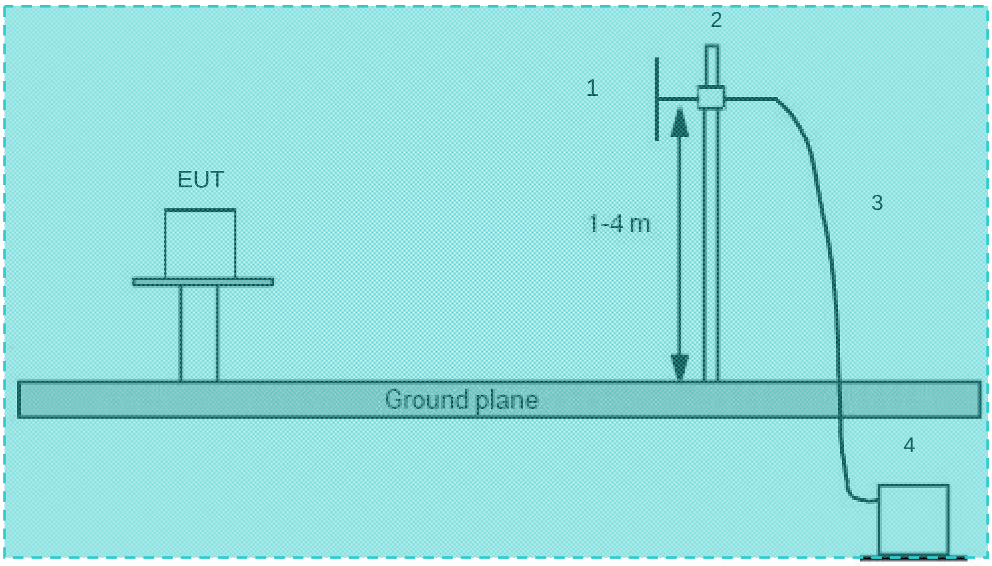

Figure 1: Illustration of the first step of the substitution method

In the first step of the substitution method the maximum radiated level of an EUT is determined. This level has no unit and does not represent a measured value. It just shows an indication value.

The substitution test site (red box) consists of an unmodulated generator, variable in frequency and power, with a power that is traceable due to calibration or alternatively a calibrated power meter (1), a suitable 50 Ω cable with indication of the cable loss (2), a suitable, calibrated attenuator (3) for coercive adaption to the antenna, consisting of real active resistances, an antenna support without influence on the test result (4) as well as a standard dipole up to 1 GHz or respectively an antenna with indication of the calibrated, isotropic gain (5).

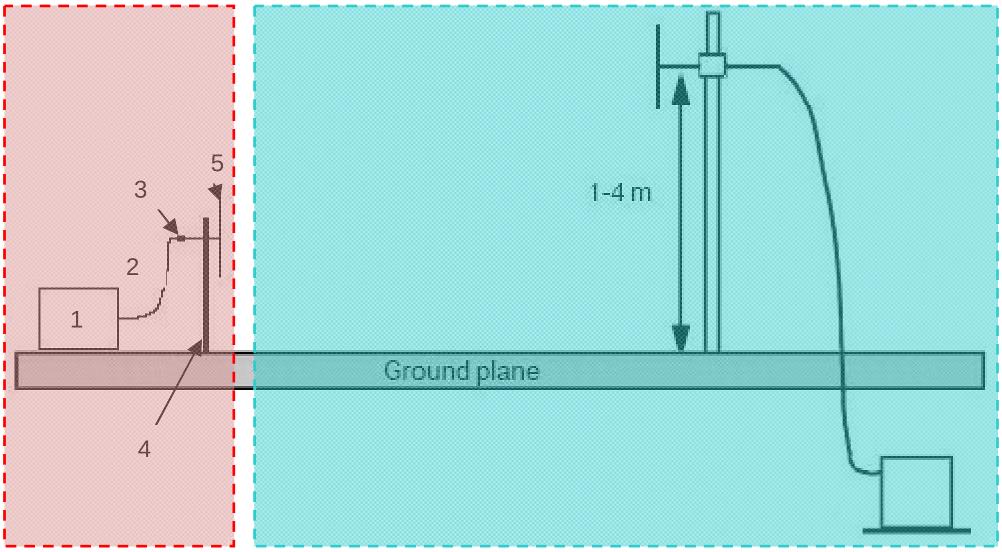

Figure 2: Illustration of the second step of the substitution method

With respect to the frequency to be measured, in the second step the generator creates a power equivalent in the level that corresponds to the indication value of the first step.

4.2 Pre-Substitution method

The pre-substitution method is a simplified procedure which cannot replace substitution. It is only feasible when it is proven that the test site is suitable for the particular test frequency range in the 30 MHz to 100 GHz range. The corresponding verification can be effected with the NSA or S_{VSWR} procedure. This verification is more difficult on other test sites than the Open Area Test Site (OATS) due to resonance effects of the metal shielding in connection with the effects of the radio absorbing materials, since in this case there are six reflecting surfaces compared to one in the OATS.

See also clause 5 of TR 102 273-2 [5].

An additional general disadvantage is, that even with a sufficient number of frequency steps it has to be interpolated between those frequency steps which in turn leads to greater measurement uncertainty.

4.2.1 Principle of radiated power measurement based on site attenuation (Pre-Substitution)

When assessing the radiated power by pre-substitution, besides peak power this method also allows other types of power evaluation.

Due to the influence of the test site and measurement equipment this method has an increased measurement uncertainty that can approximately be classified as for the field strength measurement as in CIRSPR 16-2-3 [11]. Test results close to limits need to be reassessed and rendered more precisely with the substitution method.

The determination of site attenuation requires a suitable test site that complies with the requirements of CISPR 16-1-4 [2]. In addition a RF source is required. This source comprises a standard dipole up to 1 GHz or respectively an antenna with indication of the calibrated, isotropic gain (1), an antenna support without influence on the test result (2), a suitable, calibrated attenuator (3) for coercive adaption to the antenna, consisting of real active resistances, a suitable 50 Ω cable with indication of the cable loss (4) as well as an unmodulated generator, variable in frequency and power, with a power that is traceable due to calibration or alternatively a calibrated power meter (5).

Furthermore power measuring instruments are required. These consist of a calibrated antenna with indication of the antenna gain (6), a height adjustable support (7), a suitable 50 Ω cable with indication of the cable loss (8) as well as a calibrated measuring receiver (9).

As far as possible the antenna (1) shall be mounted in the height in which the EUT will be placed for the actual measurement according to the test specification. It shall be regarded that the polarity of both antennas used needs to be equal. A known radiated power will then be created at the RF source. The measuring antenna will be adjusted to the height at which the highest power is indicated at the receiver (9). This power will be noted. The difference between transmission power and received power in dB is the site attenuation. The determination of site attenuation shall be effected with a sufficient number of frequency steps in the observed frequency range while the values shall be noted in a list.

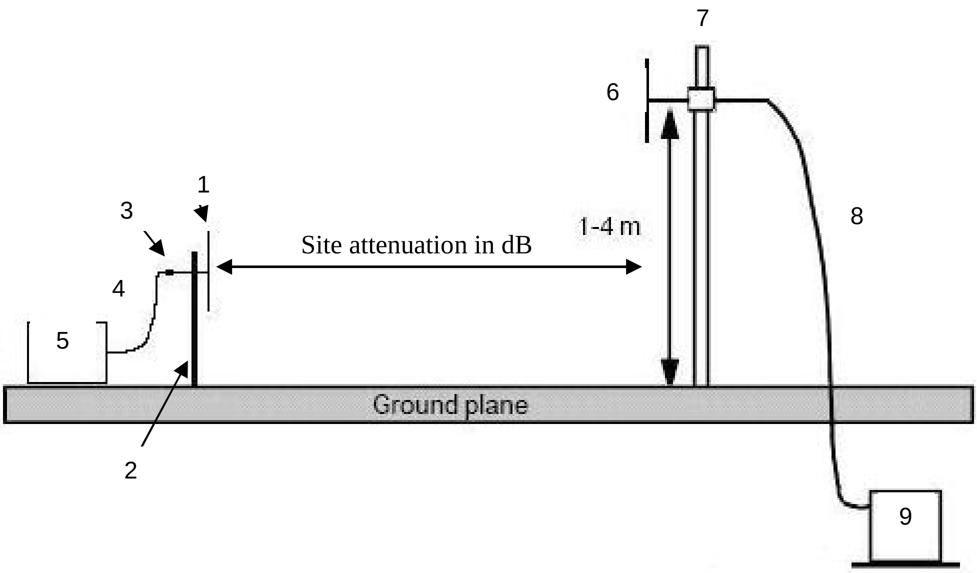

Figure 3: Example of a test site for measurements based on site attenuation

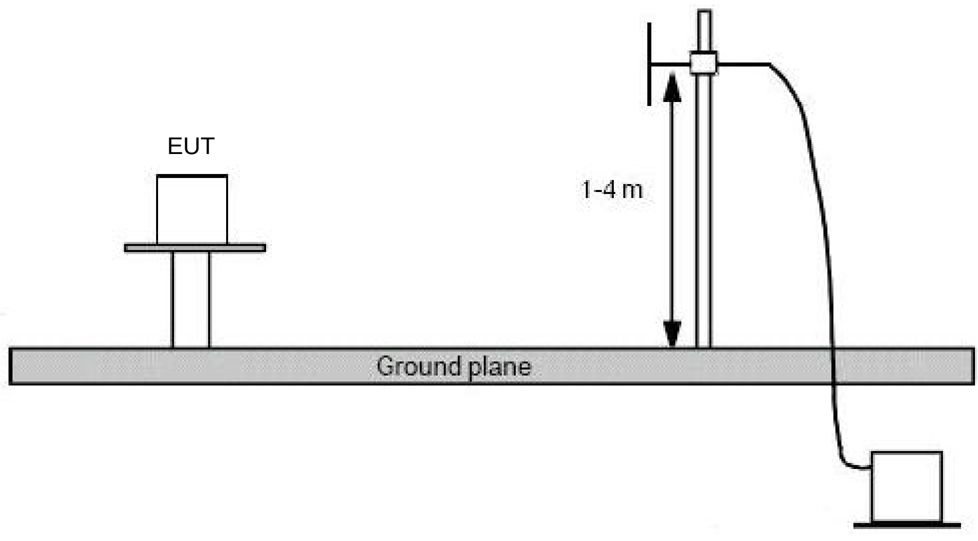

Figure 4: Example of a test site for measurements based on site attenuation

In a real test the radiated power is determined by addition of the metered value in dB with the site attenuation in dB.

4.3 Field strength measurement

4.3.1 Principle of the field strength measurement (CISPR 16)

The measurement is effected at the field strength measuring antenna in a defined distance to the EUT (e.g. in 3 m or 10 m). During field strength assessment several uncertainties are added which result from the qualification of normalized site attenuation of the test site within the $\pm$4 dB limit, the conversion from field strength into voltage, cables and connections, measuring receiver, turntable, environmental influences, deviation in polarity from the EUT antenna to the field strength measuring antenna as well as the human factor.

The maximum measurement uncertainty for field strength test sites from 30 MHz to 1 GHz in CISPR 16-4-2 [8] is indicated with 5,2 dB.

From 1 GHz to 18 GHz the field strength test site is evaluated with an S_{VSWR} qualification procedure that shows compliance with the $\pm$6 dB limit.

It shall be noted that EMC is only evaluated up to 18 GHz.

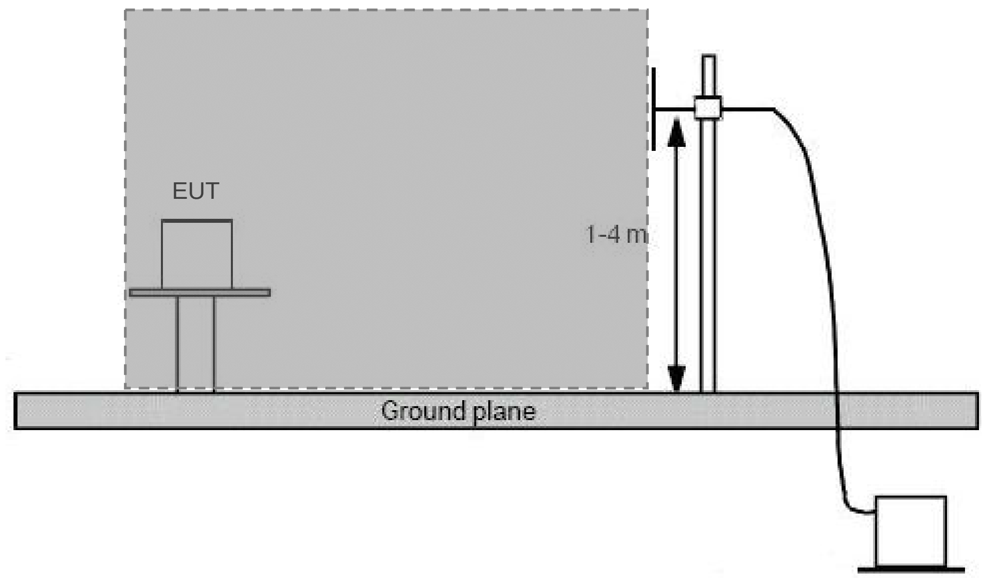

Figure 5: Example of a field strength test site (grey box)

4.4 Field strength determination for receiver sensitivity measurements

If radiated receiver sensitivity measurements are necessary, the site on which the receiver is placed shall be suitable for determination of field strength with the substitution method.

The test site consists of a modulated generator, variable in frequency and power (1), a suitable 50 Ω cable (2), an antenna support (3) as well as an antenna (4).

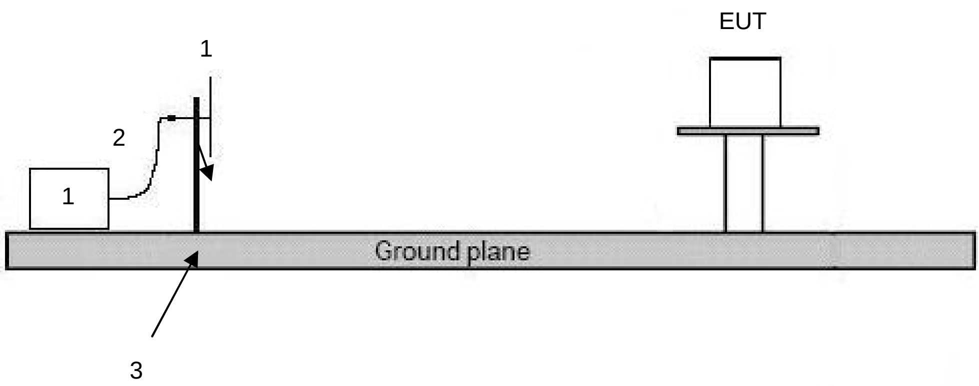

Figure 6: Example of a set up for step 1

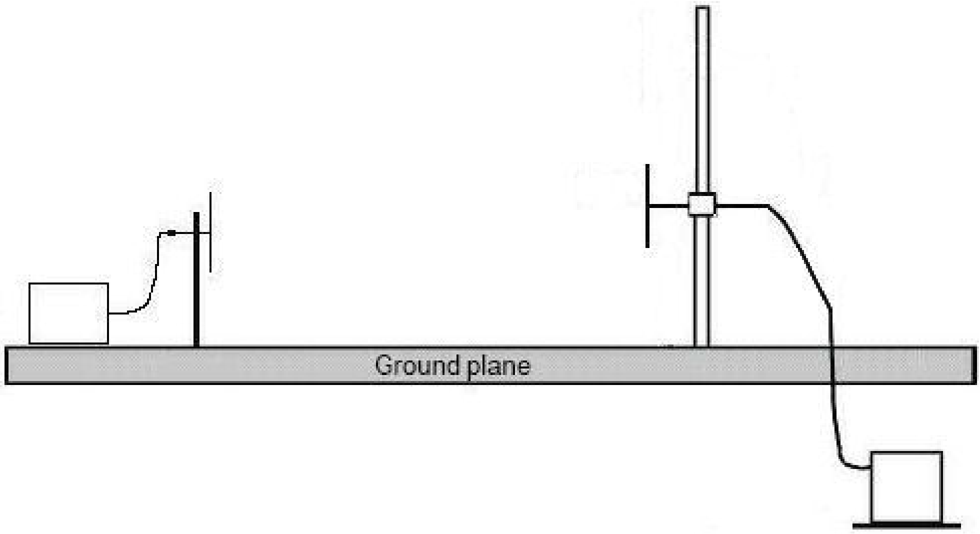

Figure 7: Example of a setup for step 2

4.4.1 Method of measurement

A test site according to the requirements of clause A.1 shall be selected. The requirements of clauses A.2 and A.3 shall be regarded.

Step 1

Signal generator A shall be placed in the location of the turntable in correspondence with the EUT's antenna polarization where possible. The EUT shall be placed in location of the test antenna and shall then be rotated in 45° increments, starting at an arbitrary orientation. At each position, the level of the signal generator shall be decreased until the requirements of clause E.2.1 are fulfilled. The level of the signal generator shall then be recorded.

Step 2

The EUT shall be replaced by a substitution antenna as defined in clause A.1.5. The signal generator shall be adjusted to each of the levels as recorded in step 1 and the corresponding field strength shall be determined.

The average, E_{mean}, is calculated from eight measurements of field strength, where the receiver is rotated in 45° increments, starting at an arbitrary orientation.

$$E_{mean} = 20\log_{10}\sqrt{\frac{8}{\sum_{i=1}^{i=8}\frac{1}{x_i^2}}}$$

Where x_i represents the eight field strengths in µV/m.

4.5 Antenna pattern measurement

4.5.1 Definition

The antenna pattern is defined as the antenna radiating efficiency in all directions relative to the antenna bore sight.

4.5.2 Method of measurements

The measurements can be made on any test site described in clause 5 using the set-up in figure 8 whereas it shall be regarded that when performing the measurement on an OATS or in a Semi-Anechoic room with conductive Ground Plane, the floor shall be covered with radio absorbing material.

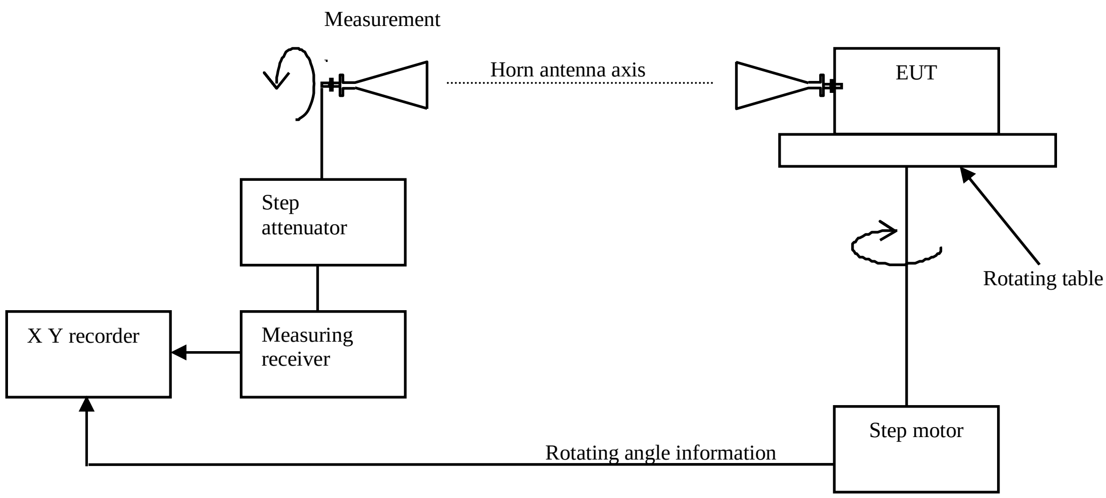

Figure 8: Test set-up for measurement of antenna pattern

The measurement antenna shall be a linear polarized horn with a gain of at least 15 dB, preferably 20 dB. Before measuring, the antenna shall be validated with regard to its characteristics. The antenna shall be able to be rotated around its radiating axis, see figure 8. The measurements antenna is connected to a measurements receiver or spectrum analyzer.

The distance between the measurements antenna and the EUT shall be sufficient to ensure that the measurements are conducted in the far-field.

The equipment under test (EUT) is placed on the rotating table to measure the horizontal antenna pattern, see figure 8.

The following steps shall be followed:

a) The transmitter is switched-on.

b) The measurement antenna is adjusted to same height as the antenna for the equipment under test (EUT).

c) The measurement antenna is adjusted in the direction of the antenna for the equipment under test (EUT).

d) The equipment antenna is adjusted in the direction of maximum reading at the measurement antenna. The direction on the rotating table is the reference direction (0 degrees on the rotating table).

e) The measurement antenna is rotated around its axis for maximum reading at the measurements receiver. The reading is the reference reading (0 dB).

f) The rotating table is rotated from -90 degrees via 0 degrees to +90 degrees and the corresponding readings on the measurement receiver are recorded. Any peaks reading of sidelobes are of interest and recorded.

g) The measurement antenna is rotated 90 degrees around its axis.

h) The measurement point f) are repeated.

i) The transmitter is switched-off.

j) The equipment under test is mounted sidewards on the rotating table (tilted by 90 degrees) to simulate measurements of vertical antenna elevation, see figure 8.

k) The transmitter is switched-on.

l) The measurement antenna is adjusted to same height as the antenna for the equipment under test (EUT).

m) The measurement antenna is adjusted in the direction of the antenna for the equipment under test (EUT).

n) The equipment antenna is adjusted in the direction of maximum reading at the measurement antenna. The direction on the rotating table is the reference direction (0 degrees on the rotating table).

o) The measurements antenna is rotated around its axis for maximum reading at the measurements receiver. The reference reading is the same as in d) above (0 dB).

p) The rotating table is rotated from -90 degrees via 0 degrees to +90 degrees and the corresponding readings on the measurement receiver shall be recorded. Any peaks reading of sidelobes are of interest and recorded.

q) The measurement antenna is rotated 90 degrees around its axis.

r) The measurement point p) is repeated.

s) The transmitter is switched-off.

The above results in total four antenna pattern measurements. The measurements a) to i) cover the horizontal antenna pattern measurements. The measurements j) to s) cover the vertical antenna pattern.

4.6 Choice of test method with regard to how close the expected result is to the standard, speed, costs, etc.

In general the measurements have the aim to determine that the protection goals regarding EMC and spectrum utilization are fulfilled. Thus certain limit values and reasonable requirements on measurement uncertainty for each measurement are required in the standards. The measurement uncertainty of the test shall be selected in such way that compliance with the required protection goals can be determined in a sufficient way. Exaggerated requirements for measurement uncertainty do not serve for better fulfilling the protection goals but make test series unnecessarily more expensive due to higher expenditures.

This can be exemplified with the methods described in clauses 4.1 and 4.2. Under consideration of measurement uncertainty as determined by the test laboratory for the particular test method, the measurement results shall be determined with a reserve displacement of at least 2 dB from the limit. Should the determined results lie within this gap of measurement uncertainty + reserve, a more accurate test method is required. Otherwise it is absolutely certain that the results are above or below the limits so that a more accurate and a more extensive determination is not necessary.

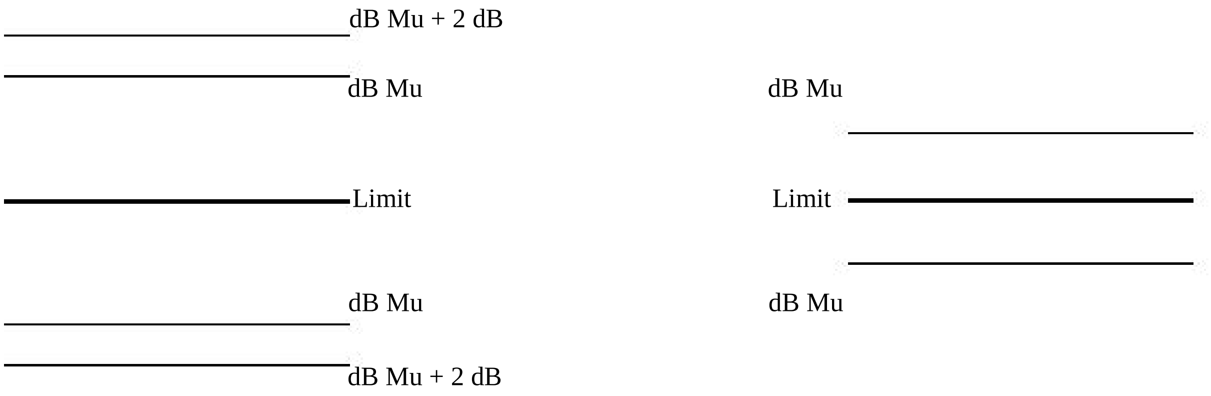

Figure 9: Example for measurement uncertainty consideration with reserve for a test method with greater measurement uncertainty and without reserve for a more accurate test method

Traceability of measurement uncertainty is not possible for certain measurement categories due to missing national comparison standards. In this case test laboratories shall refer to other accepted standards or they shall make validations by taking part in round robin tests.

5 Test sites and general arrangements

5.1 Open Area Test Site (OATS)

An Open Area Test Site comprises a turntable at one end and an antenna mast of variable height at the other set above a ground plane which, in the ideal case, is perfectly conducting and of infinite extent. In practice, whilst good conductivity can be achieved, the ground plane size has to be limited. A typical Open Area Test Site is shown in figure 10.

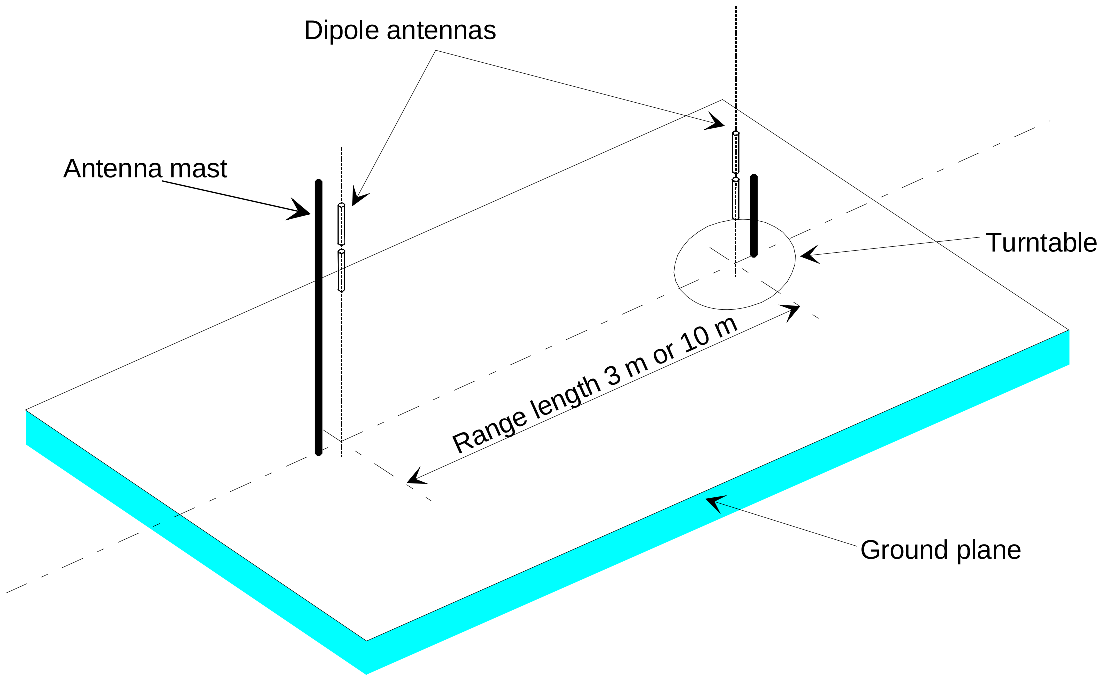

Figure 10: A typical Open Area Test Site

The ground plane creates a wanted reflection path, such that the signal received by the receiving antenna is the sum of the signals received from the direct and reflected transmission paths. The phasing of these two signals creates a unique received level for each height of the transmitting antenna (or EUT) and the receiving antenna above the ground plane.

In practice, the antenna mast provides a variable height facility so that the elevation of the test antenna can be optimized for maximum coupled signal in conjunction with the turntable for azimuth angle.

Both absolute and relative measurements can be performed on an Open Area Test Site. Where absolute measurements are to be carried out, or where the test site is to be used for accredited measurements, the Open Area Test Site should be verified. Verification involves comparison of the measured performance to that of an ideal theoretical site, with acceptability being decided on the basis of the differences not exceeding some pre-determined limits.

The Open Area Test Site has been, historically, the reference site upon which the majority, if not all, of the specification limits have been set. The ground plane was originally introduced to provide uniformity of ground conditions, between test sites, during testing.

NOTE: No part of any antenna should come within 0,25 m of the ground plane at any time throughout the tests since the antenna is influenced in its characteristics through the ground plane.

5.1.1 Testing in presence of ambient interferences (Measurement of the substituted radiation power)

- The ambient interferences shall be quantified.
- When the ambient interferences are at least 10 dB below the limits, they may be neglected.
- When the ambient interferences are within 10 dB below the limits or above the limits the measuring distance shall be reduced to λ. (max. reduction to 1 m). It shall be regarded that the aperture angle of the measuring antenna remains sufficient for capturing the complete EUT dimensions in order to achieve a better signal-to-noise ratio. In case of reflective antennas it shall be regarded the measuring distance lies within their focusing. In case of narrow-band signals of the EUT the measurement bandwidth may also be reduced.
- When the ambient interferences are within 10 dB below the limits or above the limits the substitution method shall always be used.
- Should the afore mentioned provisions not be sufficient, the test has to be conducted in an anechoic environment with calibrated measurement equipment.

5.1.2 Testing in presence of ambient interferences (Field strength measurement)

- In presence of ambient interferences the method described in annex A of CISPR 16-2-3 [11] shall be applied.
- The test site shall allow for distinction of emission from the EUT and ambient signals. Ambient signal levels should preferably be 20 dB or at least 6 dB below the desired measuring level. Having a displacement of 6 dB the level produced by the EUT can be raised by up to 3,5 dB. Suitability of the test site with regard to ambient signals can be determined by measuring the ambient signal levels, whereas the EUT is placed on the test site without being activated.
- In case of compliance testing the ambient signals level may exceed the preferred 6 dB provided that the heterodyne of the ambient noise and the EUT's emissions do not exceed the defined limit. In this case it will be assumed that the EUT complies with the limits. Other provisions may also be made e.g. reduction of the measuring bandwidth for narrowband signals and/or moving the receiving antenna closer to the EUT.
- If the ambient field strength level within the defined measurement ranges exceeds the limits, the following alternatives can be applied:
    - Measuring in smaller distances, whereas the results are extrapolated with regard to the distance for which the limits are defined. The extrapolation equation shall either be consistent with the equation recommended in the product standard or its accuracy needs to be verified with measurements in not less than three different distances.

NOTE: The term "accuracy" is defined, in relation to the measured value, in clause 4.1.1 of TR 102 273 [5].

- Where needed, measurements in the critical frequency bands shall be conducted at a time of the day when ambient interferences are lower (daytime absorption).
- Should the afore mentioned provisions not be sufficient, the test has to be conducted in an anechoic environment with calibrated measurement equipment.

5.2 Other test sites

The test sites described below are equipped with absorbers for attenuation of reflexions. These absorbers' efficiency is subject to a lower and an upper cut-off frequency. For the use at higher frequencies suitability of these test sites has to be verified with regard to attenuation of reflexions, resonances in connection with the chamber as well as imaging.

5.2.1 Test sites with radio absorbing material

5.2.1.1 Semi-Anechoic Rooms with a conductive Ground Plane

A Semi-Anechoic Room with a conductive Ground Plane is an enclosure, usually shielded, whose internal walls and ceiling are covered with radio absorbing material, normally of the pyramidal urethane foam type. The floor, which is metallic, is not covered and forms the ground plane. The room usually contains an antenna mast at one end and a turntable at the other. A typical Semi-Anechoic Room with a conductive Ground Plane is shown in figure 11.

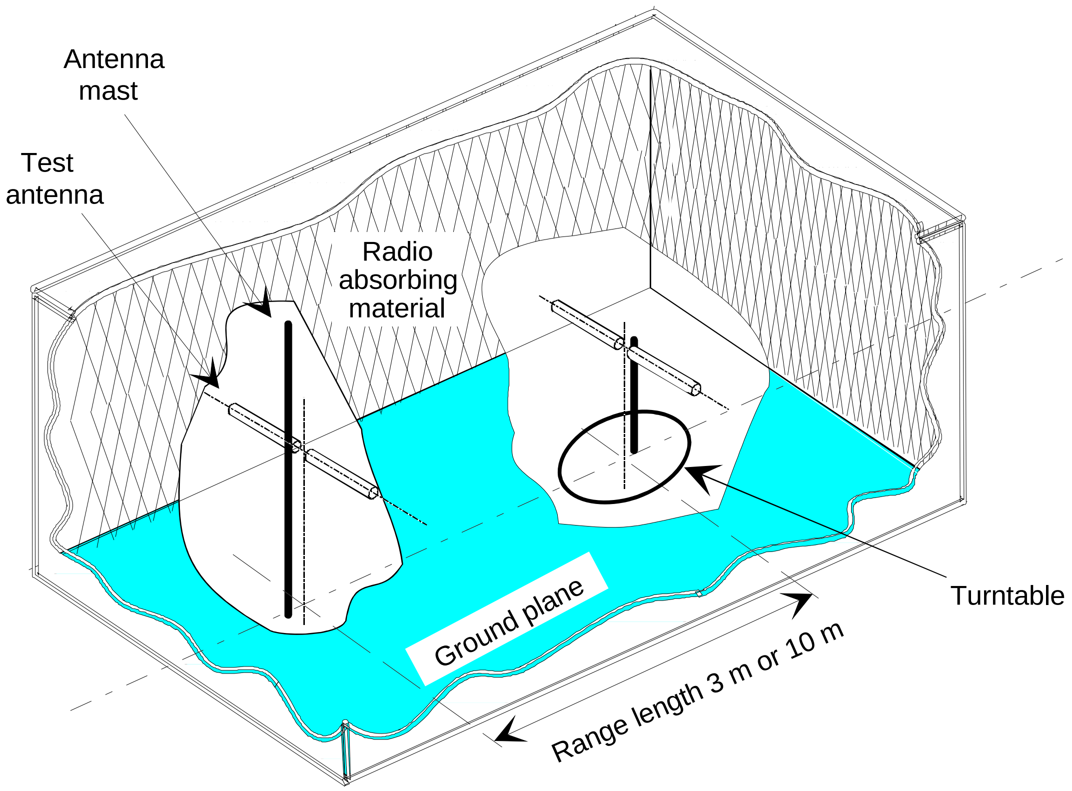

Figure 11: A typical Semi-Anechoic Room with a conductive Ground Plane

This type of test room attempts to simulate an ideal Open Area Test Site (historically, the reference site upon which the majority, if not all, of the specification limits have been set) whose primary characteristic is a perfectly conducting ground plane of infinite extent.

The room shielding and radio absorbing material work together to provide a controlled environment for testing purposes. The shielding provides a test space with reduced levels of interference from ambient signals and other outside effects, whilst the radio absorbing material minimizes unwanted reflections from the walls and ceiling which can influence the measurements.

In practice whilst it is relatively easy for shielding to provide high levels (80 dB to 140 dB) of ambient interference rejection (normally making ambient interference negligible), no design of radio absorbing material satisfies the requirement of complete absorption of all the incident power. For example it cannot be perfectly manufactured and installed and its return loss (a measure of its efficiency) varies with frequency, angle of incidence and in some cases, is influenced by high power levels of incident radio energy. To improve the return loss over a broader frequency range, ferrite tiles, ferrite grids and hybrids of urethane foam and ferrite tiles are used with varying degrees of success.

The ground plane creates the wanted reflection path, such that the signal received by the receiving antenna is the sum of the signals received from the direct and reflected transmission paths. The phasing of these two signals creates a unique received signal level for each height of the transmitting antenna (or EUT) and the receiving antenna above the ground plane.

In practice, the antenna mast provides a variable height facility so that the elevation of the test antenna can be optimized for maximum coupled signal in conjunction with the turntable for azimuth angle, between antennas, or, between an EUT and a test antenna.

Both absolute and relative measurements can be performed in a Semi-Anechoic Room with a Ground Plane. Where absolute measurements are to be carried out, or where the test facility is to be used for accredited measurements, the chamber should be verified. Verification involves comparison of the measured performance to that of an ideal theoretical room, with acceptability being decided on the basis of the differences not exceeding some pre-determined limits.

NOTE: No part of any antenna should come within 0,25 m of the ground plane at any time throughout the tests since the antenna is influenced in its characteristics through the ground plane.

5.2.1.2 Fully Anechoic Rooms (FAR)

A Fully Anechoic Room is an enclosure whose internal walls, floor and ceiling are covered with radio absorbing material, normally of the pyramidal urethane foam type. It is normally shielded against local ambient. The room contains an antenna support at one end and a turntable at the other. A typical Anechoic Room is shown in figure 12 with dipole antennas at both ends.

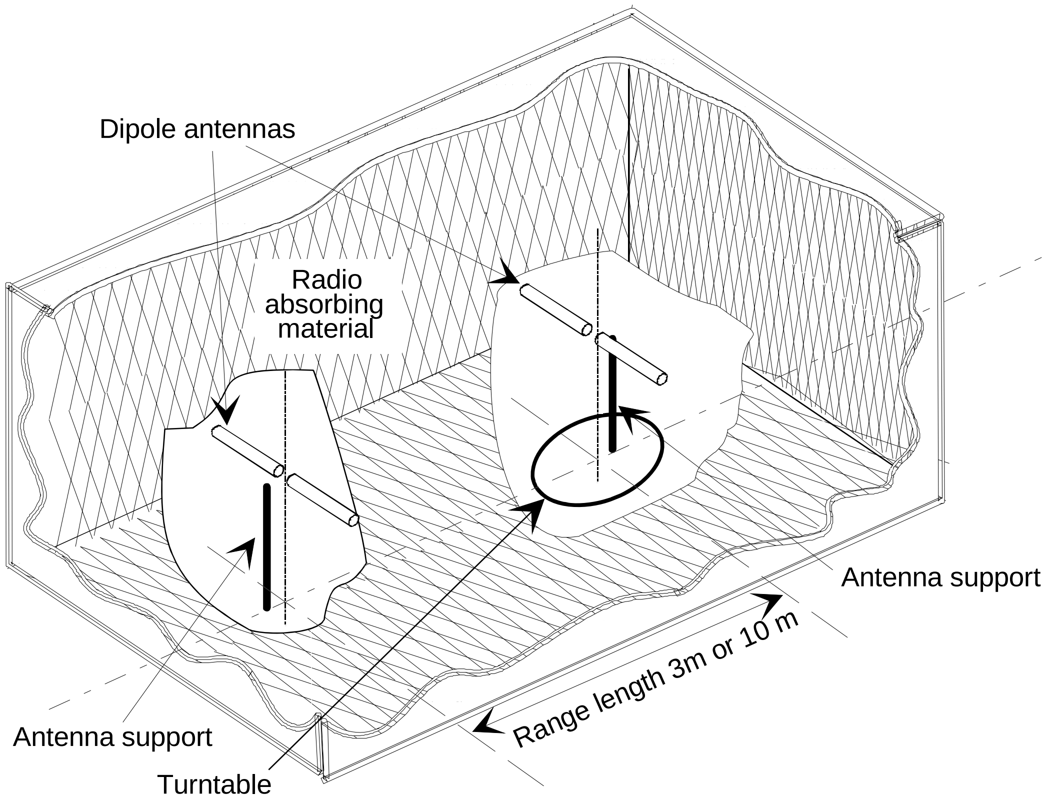

Figure 12: A typical Anechoic Chamber

The room shielding and radio absorbing material work together to provide a controlled environment for testing purposes. This type of test room attempts to simulate free space conditions. The shielding provides a test space, with reduced levels of interference from ambient signals and other outside effects, whilst the radio absorbing material minimizes unwanted reflections from the walls, floor and ceiling which could influence the measurements.

In practice whilst it is relatively easy for the shielding to provide high levels (80 dB to 140 dB) of ambient interference rejection (normally making ambient interference negligible), no design of radio absorbing material satisfies the requirement of complete absorption of all the incident power. For example it cannot be perfectly manufactured and installed and its return loss (a measure of its efficiency) varies with frequency, angle of incidence and in some cases, is influenced by high power levels of incident radio energy. To improve the return loss over a broader frequency range, ferrite tiles, ferrite grids and hybrids of urethane foam and ferrite tiles are used with varying degrees of success.

The Anechoic Room generally has several advantages over other test facilities. There is minimal ambient interference, minimal floor, ceiling and wall reflections and it is independent of the weather. It does however have some disadvantages which include limited measuring distance (due to available room size, cost, etc.) and limited lower frequency usage due to the size of the room and the pyramidal absorbers.

Both absolute and relative measurements can be performed in a Fully Anechoic Room. Where absolute measurements are to be carried out, or where the test facility is to be used for accredited measurements, the room should be verified. Verification involves comparison of the measured performance to that of an ideal theoretical chamber, with acceptability being decided on the basis of the maximum difference between the two.

When measuring in an anechoic chamber above 1 GHz and without a height scan of the "comparison antenna", instead of performing 360° increments with a turntable the EUT would have to be moved orthogonally around all its surfaces in order to measure the maximum radiated RF power due to the narrow antenna pattern occurring at high frequencies.

NOTE 1: No part of any antenna should come within 0,25 m of the floor absorber at any time throughout the tests since the antenna is influenced in its characteristics through the ground plane.

NOTE 2: For the fully anechoic chamber, no part of the volume of the EUT should, at any angle of rotation of the turntable, fall outside the "quiet zone" of the chamber at the nominal frequency of the test.

NOTE 3: The "quiet zone" is a volume within the anechoic chamber (without a ground plane) in which a specified performance has either been proven by test, or is guaranteed by the designer/manufacture. The specified performance is usually the reflectivity of the absorbing panels or a directly related parameter (e.g. signal uniformity in amplitude and phase). It should be noted however that the defining levels of the quiet zone tend to vary.

5.2.3 Reflecting test sites

5.2.3.1 Electromagnetic reverberation chambers (RVC)

This test site is rather not useful for radiated measurements since this site averages in an undefined way which means that it is unsuitable for mean value measurements. Peak value measurements and measurements of fast chirps are not feasible due to retention periods in the chamber which leads to rounding. Since there is no directional propagation, measurements of antenna pattern are also not possible.

5.2.4 Minimum requirements for test sites for measurements above 18 GHz

Generally the test site shall be adequate to allow for testing in the far field of the EUT. The test site should therefore consist of an electromagnetic anechoic room where either at least the ground surface is covered with radio absorbing material or up to six surrounding surfaces are covered with radio absorbing material. The absorbing material shall have a minimum attenuation of 30 dB. It shall be verified that reflections are sufficiently reduced. The test site shall have the following dimensions:

- Width of 2 meters.
- Length of 3 meters.
- Height of 2 meters (only applicable for a room with more than one reflecting surface).

Highly directional receiving antennas help in reducing reflections. The use of standard gain horn antennas is recommended. It shall be noted that if the antenna aperture is smaller than the EUT, sufficient measurements in both azimuth and elevation shall be conducted in order to ensure that the maximum radiation is determined.

The measuring distance shall be selected in such way that antenna coupling effects are avoided. A distance of at least 0,5 m is therefore recommended. The EUT may be positioned at any height that minimizes reflections from the floor.

Due to high loss of coaxial cables at higher frequencies, the connection from the receiving antenna to the measuring receiver should not exceed 1 m, thus making it necessary to place the measuring receiver very close. This is especially the case when using external harmonic mixers with very short connections to the measuring receiver. Therefore the measuring receiver should somehow be covered with radio absorbing material in direction to the measuring field in order to reduce reflections.

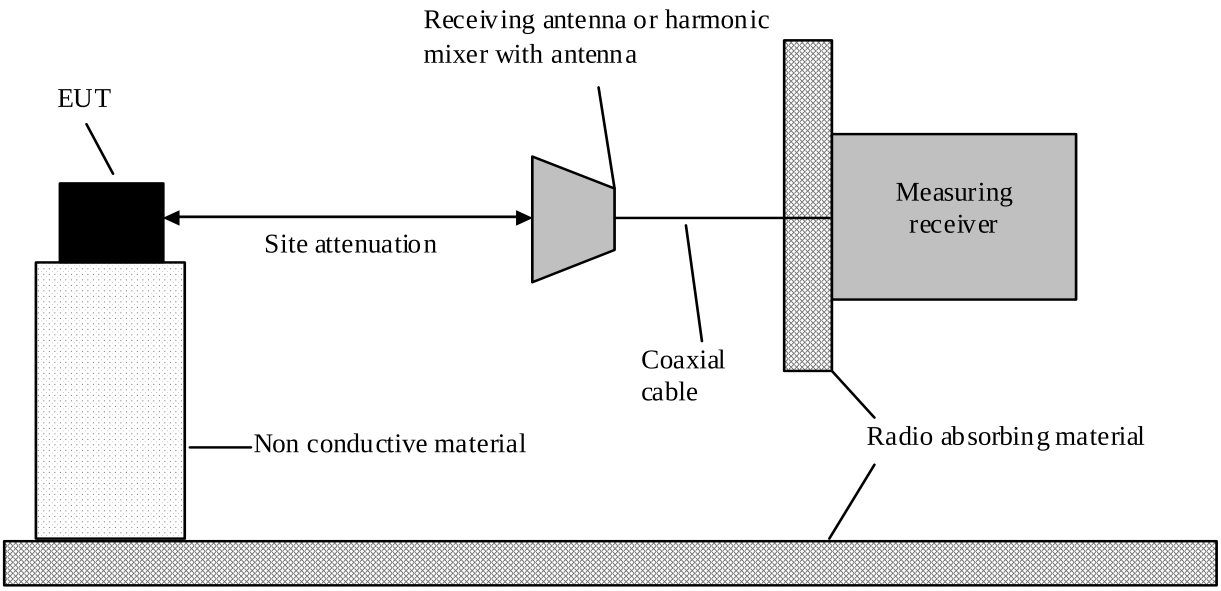

Figure 13: Example of a test site above 18 GHz with one reflecting surface

Site attenuation of the test site can be determined as described in clause 4.2.1. Should the test site in its characteristics be nearly ideal, it may be possible to use the theoretical Free Space Loss (FSL) as site attenuation.

Table 1: Example of Free Space Loss at 1 m distance

Measuring distance/m	f/GHz	λ/m	[FSL]/dB
1	24,2	0,012397	60,12
	48,4	0,006198	66,14
	72,6	0,004132	69,66
	96,8	0,003099	72,16

Table 2: Example of Free Space Loss at 0,5 m distance

Measuring distance/m	f/GHz	λ/m	[FSL]/dB
0,5	24,2	0,012397	54,1
	48,4	0,006198	60,12
	72,6	0,004132	63,64
	96,8	0,003099	66,14

Table 3: Example of Free Space Loss at 0,25 m distance

Measuring distance/m	f/GHz	λ/m	[FSL]/dB
0,25	72,6	0,004132	57,62
	96,8	0,003099	60,12

Whereas:

$\lambda = c/f$

$[FSL] = 10 \log (4\pi r/\lambda)^2$

5.3 Antennas

5.3.1 Test antenna

A test antenna is always used in radiated test methods. In emission tests (i.e. effective radiated power, radiated spurious emissions) the test antenna is used to detect the field from the EUT in one stage of the measurement and from the substitution antenna in the other stage. For tests of receiver parameter of EUTs with integrated or dedicated antennas (i.e. sensitivity, blocking, adjacent channel selectivity, etc.) the test antenna is used to radiate a field to the EUT or to the substitution antenna.

The test antenna should be mounted on a support capable of allowing the antenna to be used in either horizontal or vertical polarization. On ground plane sites (i.e. anechoic chambers with ground planes and Open Area Test Sites), the test antenna should additionally allow the height of its centre above the ground to be varied over the specified range (usually 1 m to 4 m).

For the test in the frequency range from 25 MHz to 1 000 MHz a biconical and a log periodical dipole array antenna or combination thereof (commonly termed "log periodic") could be used to cover the entire band. Above 1 000 MHz waveguide horns are recommended although, again, log periodic could be used.

The length of the test antenna along the measurement axis shall not exceed 20 % of the measuring distance. Furthermore the distance between the lower extremity of the measuring antenna and the ground shall be at least 300 mm.

NOTE 1: The gain of a horn antenna is generally expressed relative to an isotropic radiator.

For radiated measurements of transmitters, the test antenna is connected to a calibrated measuring receiver capable of being tuned to any frequency under investigation. The test antenna is connected to a calibrated signal generator for receiver parameter tests.

NOTE 2: The use of filters may be necessary in order to suppress certain wanted signals.

5.3.2 Substitution antenna

The substitution antenna is used to replace the EUT for tests in which transmitting parameters (i.e. effective radiated power, radiated spurious emissions) are being measured. In this case the antenna acts as a reference radiator to transmit a known radiated power.

The substitution antenna is also used to measure a certain field at the position of the EUT for receiver parameter measurements.

In the frequency band 25 MHz to 1 000 MHz, the substitution antenna should be a $\lambda/2$ dipole antenna (constructed in accordance with ANSI C63.5 [6] is generally recommended). For frequencies of 80 MHz and above, the dipoles should have their arm lengths set for resonance at the frequency of test. Below 80 MHz, shortened arm lengths are recommended. Where a shortened dipole antenna is used at these frequencies, details of the type of antenna used shall be included with the results of the tests and correction factors shall be taken into account. For measurements above 1 000 MHz, a standard gain horn or calibrated horn antenna is recommended although, log periodic could be used.

The centre of this antenna shall coincide with the reference point of the EUT 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 300 mm. Usually the centre of a horn antenna is defined as the aperture plane.

For radiated measurements of transmitter parameters or receiver spurious emission the substitution antenna is connected to a calibrated signal generator capable to generate levels to any frequencies under investigation.

The substitution antenna shall be connected to a calibrated measuring receiver when the site is used for the measurement of receiver parameters. The signal generator and the receiver shall be connected to the antenna through suitable matching and balancing networks.

5.3.3 Signalling antenna

In certain cases the EUT requires some signalling in order to provide its operating or test modes which can be effected by a corresponding signalling antenna. It shall be ensured that this antenna has no coupling effects against the test or substitution antenna.

6 Guidance on the use of radiation test sites

This clause details procedures, test equipment arrangements and verification that should be carried out before any of the radiated test are undertaken. These schemes are common to all types of test sites described in clause 5.

6.1 Verification

No test should be carried out on a test site which does not possess a valid certificate of verification. The verification procedures for the different types of test sites described in clause 5 (i.e. anechoic chamber, anechoic chamber with a ground plane and Open Area Test Site) are given in the relevant parts of TR 102 273 [5] or equivalent.

6.2 Preparation

The cables for both ends of the test site should be routed horizontally away from the testing area for a minimum of 2 m (unless, in the case both types of anechoic chamber, a back wall is reached) and then allowed to drop vertically and out through either the ground plane or screen (as appropriate) to the test equipment. Precautions should be taken to minimize pick up on these leads (e.g. dressing with ferrite beads, or other loading). The cables, their routing and dressing should be identical to the verification set-up.

NOTE 1: For ground reflection test sites (i.e. anechoic chambers with ground planes and Open Area Test Sites) which incorporate a cable drum with the antenna mast, the 2 m requirement may be impossible to comply with.

Calibration data for all items of test equipment should be available and valid. For test, substitution and measuring antennas, the data should include gain relative to an isotropic radiator (or antenna factor) for the frequency of test. Also, the VSWR of the substitution and measuring antennas should be known.

The calibration data on all cables and attenuators should include insertion loss and VSWR throughout the entire frequency range of the tests. All VSWR and insertion loss figures should be recorded in the log book results sheet for the specific test.

Where correction factors/tables are required, these should be immediately available.

For all items of test equipment, the maximum errors they exhibit should be known along with the distribution of the error e.g.:

- cable loss: ±0,5 dB with a rectangular distribution;
- measuring receiver: 1,0 dB (standard deviation) signal level accuracy with a Gaussian error distribution.

NOTE 2: The term "accuracy" is defined, in relation to the measured value, in clause 4.1.1 of TR 102 273 [5].

At the start of measurements, system checks should be made on the items of test equipment used on the test site.

6.3 Power supplies (to the EUT)

All tests should be performed using power supplies wherever possible, including tests on EUT designed for battery-only use. In all cases, power leads should be connected to the EUT's supply terminals (and monitored with a digital voltmeter) but the battery should remain present, electrically isolated from the rest of the equipment, possibly by putting tape over its contacts.

The presence of these power cables can, however, affect the measured performance of the EUT. For this reason, they should be made to be "transparent" as far as the testing is concerned. This can be achieved by routing them away from the EUT and down to the either the screen, ground plane or facility wall (as appropriate) by the shortest possible paths. Precautions should be taken to minimize pick-up on these leads (e.g. the leads could be twisted together, loaded with ferrite beads at 0,15 m spacing or otherwise loaded).

6.4 Settings

Settings will vary with the type of equipment being used and the EUT. Please ensure that you have fully researched the EUT and fully understand its parameters including bandwidth frequency and power.

6.5 Range length except for field strength test sites as per CISPR 16

- It shall be ensured that the measurements are based on the constant free space resistance.

It shall be ensured that radiated measurements are tested in the far field. There is no clearly defined transition from near field to far field. However, it can be assumed that far field conditions are present in a distance of λ of the wave length to be tested. whereas the distance should be equal to or exceed:

$$\frac{2\left(d_1 + d_2\right)^2}{\lambda}$$

where:

d1 is the largest dimension of the EUT/dipole after substitution (m);

d2 is the largest dimension of the test antenna (m);

λ is the test frequency wavelength (m).

Smaller distances are in the near field. Measurements in the near field lead to fraud of test results, since the constant free space resistance is not formed exclusively.

- It shall be ensured that mutual electromagnetic influences of antennas are avoided.

Electromagnetic influences of antennas depend on the distance between the antennas as well as the antenna shape in connection with frequency.

- At short measuring distances in the microwave area with highly directional antennas it has to be considered that the distance lies outside the antennas' focussing range.

Above 1 GHz antenna factors are related to an isotropic radiator. It has to be regarded that the measuring distance is in the far field and outside of the antenna focus.

6.6 Coupling of steering, modulation and demodulation signals

6.6.1 Temporary connections and electrical lines

When using temporary connectors or lines for measurements in the radiated field it has to be regarded that the presence of such galvanic leads in the radiated field may cause a disturbance of that field and may lead to false test results. These disturbances can be minimized by using suitable coupling methods, offering signal isolation and minimum field disturbance (e.g. optical and acoustic coupling).

6.6.2 Data Signals

Isolation can be provided by the use of optical, ultra sonic or infra red means. Field disturbance can be minimized by using a suitable fibre optic connection. Ultra sonic or infra red radiated connections require suitable measures for the minimization of ambient noise.

6.6.3 Speech and analogue signals

Where an audio output socket is not available an acoustic coupler should be used.

When using the acoustic coupler, care should be exercised that possible ambient noise does not influence the test result.

6.6.3.1 Acoustic coupler description

The acoustic coupler comprises a plastic funnel, an acoustic pipe and a microphone with a suitable amplifier. The materials used to fabricate the funnel and pipe should be of low conductivity and of low relative dielectric constant (i.e. less than 1,5).

- The acoustic pipe should be long enough to reach from the EUT to the microphone which should be located in a position that will not disturb the RF field. The acoustic pipe should have an inner diameter of about 6 mm and a wall thickness of about 1,5 mm and should be sufficiently flexible so as not to hinder the rotation of the turntable.

- The plastic funnel should have a diameter appropriate to the size of the loudspeaker in the EUT, with soft foam rubber glued to its edge, it should be fitted to one end of the acoustic pipe and the microphone should be fitted to the other end. It is very important to fix the centre of the funnel in a reproducible position relative to the EUT, since the position of the centre has a strong influence on the frequency response that will be measured. This can be achieved by placing the EUT in a close fitting acoustic mounting jig, supplied by the provider, of which the funnel is an integral part.

- The microphone should have a response characteristic flat within 1 dB over a frequency range of 50 Hz to 20 kHz, a linear dynamic range of at least 50 dB. The sensitivity of the microphone and the receiver audio output level should be suitable to measure a signal to noise ratio of at least 40 dB at the nominal audio output level of the EUT. Its size should be sufficiently small to couple to the acoustic pipe.

- The frequency correcting network should correct the frequency response of the acoustic coupler so that the acoustic SINAD measurement is valid.

6.7 Calibration

All tests (results) shall be conducted in a reproducible and traceable manner including corresponding measurement uncertainty. Therefore it is compulsory to calibrate test sites. Calibration of a test site including all single instruments should be conducted according to the Guide to the expression of uncertainty in measurement [7] and ISO/IEC 17025 [9]. Measurement uncertainties shall be derived from national comparison standards. Calibration cycles shall be selected in such way that there is high assurance for avoiding inaccurate results caused by inaccurate instruments.

6.8 Standard test position

The standard position in all test sites for equipment which is not intended to be worn on a person, including hand-held equipment, shall be on a non conducting support with an εr as close as possible to one, height 1,5 m, capable of rotating about a vertical axis through the equipment. The standard position of the equipment shall be the following:

a) for equipment with an internal antenna, it shall be placed in the position closest to normal use as declared by the provider;

b) for equipment with a rigid external antenna, the antenna shall be vertical;

c) for equipment with a non-rigid external antenna, the antenna shall be extended vertically upwards by a non-conducting support.

Equipment which is intended to be worn on a person may be tested using a simulated man as support.

The simulated man comprises a rotatable acrylic tube filled with salt water, placed on the ground.

The container shall have the following dimensions:

- Height: 1,7 ± 0,1 m;
- Inside diameter: 300 ± 5 mm;
- Sidewall thickness: 5 ± 0,5 mm.

The container shall be filled with a salt (NaCl) solution of 1,5 g per litre of distilled water.

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

NOTE: To reduce the weight of the simulated man it may be possible to use an alternative tube which has a hollow centre of 220 mm maximum diameter.

6.9 Test fixtures

Basic instructions and requirements for the use of test fixtures can be found in the TR 102 273 [5].

6.9.1 Introduction

Test fixtures are tools that allow the measurement of certain radio parameters of a EUT whilst it is subjected to extremes of either voltage or temperature or both. They only allow relative measurements to be carried out since its coupling mechanism to the EUT is extremely complex, making it virtually impossible to calculate an absolute coupling factor.

Only after it has been verified that the test fixture does not affect performance, the EUT can be confidently tested under extreme conditions. As a result of verifying the test fixture and equating the performance of the EUT in the test fixture under normal conditions to results taken on a free field test site, the EUTs performance at an extreme condition can be directly related to the free-field measurements.

With equipment intended for use with a small aperture integral antenna, and not equipped with a 50 Ω RF output connector, a suitable test fixture as shown in figure 14 shall be used.

Where a test fixture as defined in the present clause is used for measurements on integral antenna equipment, tests regarding frequency drift, power drift, bandwidth or receiver sensitivity shall be carried out using the test fixture. This fixture is a radio frequency device for coupling the integral antenna to a 50 Ω RF terminal at all frequencies for which measurements need to be performed.

The test fixture shall be fully described.

In addition, the test fixture may provide:

a) a connection to an external power supply;

b) a method to provide the input to or output from the equipment. This may include coupling to or from the antenna. In case of assessment of speech equipment, an audio interface may be provided by direct connection or by an acoustic coupler or in case of non-speech equipment, the test fixture could also provide the suitable coupling means e.g. for data or video outputs.

The test fixture shall normally be supplied by the provider.

The performance characteristics of the test fixture shall be validated by the testing laboratory and shall conform to the following basic parameters:

a) the attenuation of the test fixture coupling shall be such that sufficient dynamic range is given. This can vary depending on each test method and shall thus be validated before the measurements. If the attenuation is too great it can be compensated by linear amplification outside the test-fixture. Care should be taken that the amplification factor is not affected by the temperature;

b) adequate bandwidth properties;

c) a coupling loss variation over the frequency range used in the measurement which does not exceed 2 dB, if the coupling factor has not been determined individually for each test frequency at normal test conditions (20 °C, Unom);

d) circuitry associated with the RF coupling shall contain no active or non-linear devices;

e) the VSWR at the 50 Ω socket shall not be more than 1,5 over the frequency range of the measurements;

f) the coupling loss shall be independent of the position of the test fixture in the test environment and be unaffected by the proximity of surrounding objects or people. The coupling loss shall be reproducible when the equipment under test is removed and replaced. Normally, the text fixture is in a fixed position and provides a location for the EUT;

g) the coupling loss shall remain substantially constant when the environmental conditions are varied.

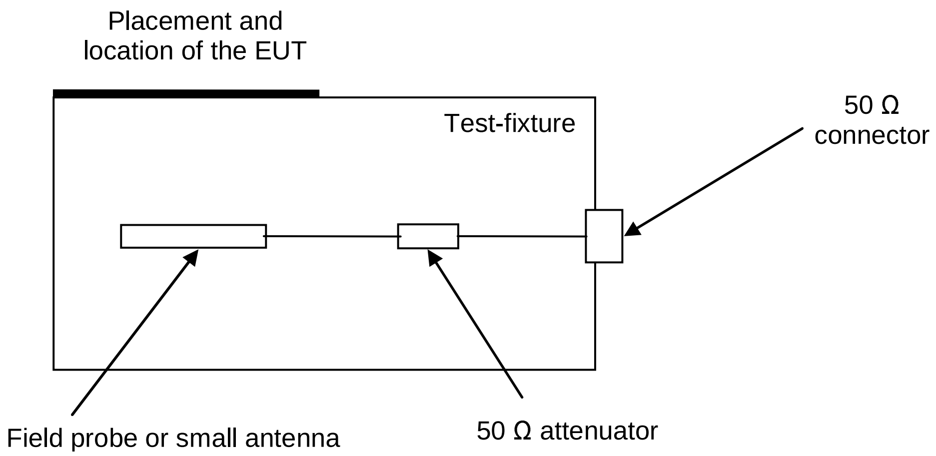

Figure 14: Example of a test fixture

The field probe (or small antenna) needs to be properly terminated.

The characteristics and validation shall be mentioned in the test report if appropriate.

6.9.2 Measurement procedure for transmitter tests under extreme conditions

Step 1

A measurement of the transmitter output power has to be performed on a test site according to clause 5 on all applicable channels (test frequencies).

Step 2

The transmitter under test has to be placed in the test fixture and both have to be brought in the temperature chamber. The test fixture has to be connected to a spectrum analyser. The transmitter has to be switched on and the transmitter output power has to be measured under normal conditions on all applicable channels and with the same spectrum analyser settings as used in Step 1.

The coupling loss has to be calculated with following formula for each test frequency.

K = P1 - P2

Where:

P1 = Power measured in Step 1

P2 = Power measured in the test fixture under normal conditions

This correction factor has to be respected for all measurements under normal and extreme conditions with the test fixture.

Care should be taken, that the coupling loss won't be change during the further measurements by changing the setup.

Step 3

The measurement has to be performed under normal and extreme conditions (temperature and voltage) with the respected correction factor determined in step 2.

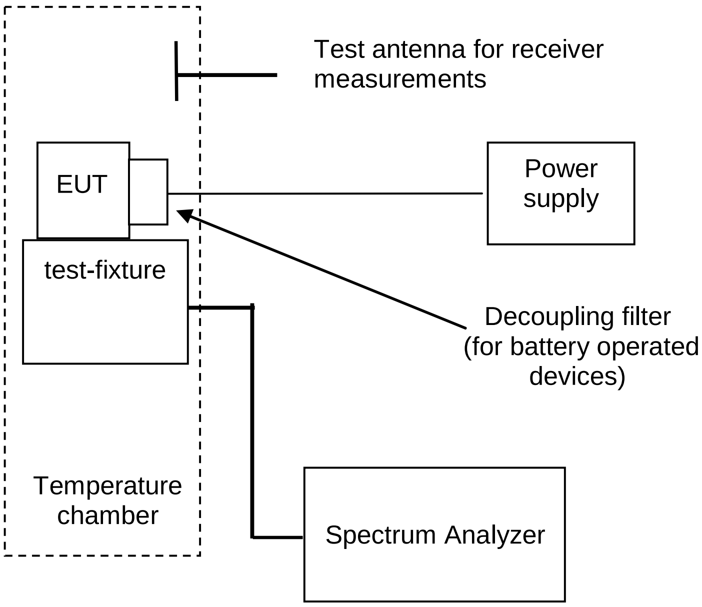

Figure 15: Example of a test setup

6.9.3 Measurement procedure for receiver sensitivity tests under extreme conditions

Step 1

A measurement of the receiver sensitivity has to be performed on a test site according to clause 5 on all applicable channels (test frequencies).

Step 2

The receiver under test has to be placed in the test fixture and both have to be brought in the climatic chamber. The test fixture has to be connected to a suitable generator which generates the wanted signal. The receiver has to be switched on and its sensitivity has to be determined by reducing the generator level under normal conditions and with the same generator settings as used in Step 1.

The coupling loss has to be calculated with following formula for each test frequency.

$$K = P1 - P2$$

Where:

P1 = sensitivity measured in Step 1

P2 = sensitivity measured in the test fixture under normal conditions

This correction factor has to be respected for all measurements under normal and extreme conditions with the test fixture.

Care should be taken, that the coupling loss won't be changed during the further measurements by changing the setup and that the generator itself has a sufficient shielding to avoid direct coupling.

Step 3

The measurement has to be performed under extreme conditions (temperature and voltage) with the respected correction factor determined in step 2.

6.9.4 Validation of the test-fixture in the climatic facility

This test is only needed if test fixture measurements are performed under extreme temperature conditions.

The method described in the present clause is only an example for validation of a test fixture. It is also possible to use other methods under good engineering practice that lead to a retraceable result. In any case the validation should be documented accordingly.

Step 1

The test fixture is brought into a temperature chamber. A transmit antenna connected to a signal generator shall be positioned from the test-fixture at a far field distance of not less than one λ at the frequency. The test fixture consists of the mechanical support for the EUT, an antenna or field probe and a 50 Ω attenuator for proper termination of the field probe. The test fixture shall be connected to a spectrum analyzer via the 50 Ω connector. A signal generator has to be set on the EUT's nominal frequency (see figure 16). The unmodulated output power of the signal generator has to be set to a value such that a sufficiently high level can be observed with the spectrum analyzer. This determined value shall be recorded. The signal generator shall then be set to the upper and the lower band limit of the EUT's assigned frequency band. The measured values shall not deviate more than 1 dB from the value at the nominal frequency. The distance between test antenna and test fixture may be reduced to λ\2 for frequencies below 100 MHz.

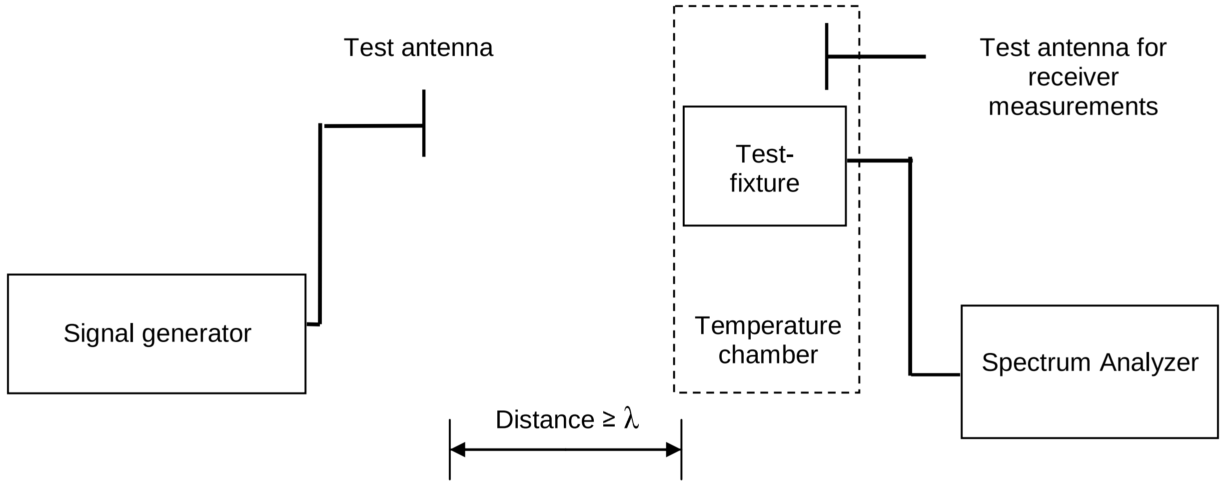

Figure 16: Example of a validation of test set-up without EUT

If receiver tests under extreme temperature conditions are performed, a receiver test antenna or signalling antenna is also brought into the temperature chamber to ensure its influence in the chamber is known.

Step 2

During validation and testing the EUT shall be fitted to the test fixture in a switched-off mode as shown in figure 17. Step 1 shall be repeated, this time with the EUT in place. The measured values shall be compared with those from step 1 and may not vary by more than 2 dB. This shows that the EUT does not cause any significant shadowing of the radiated power.

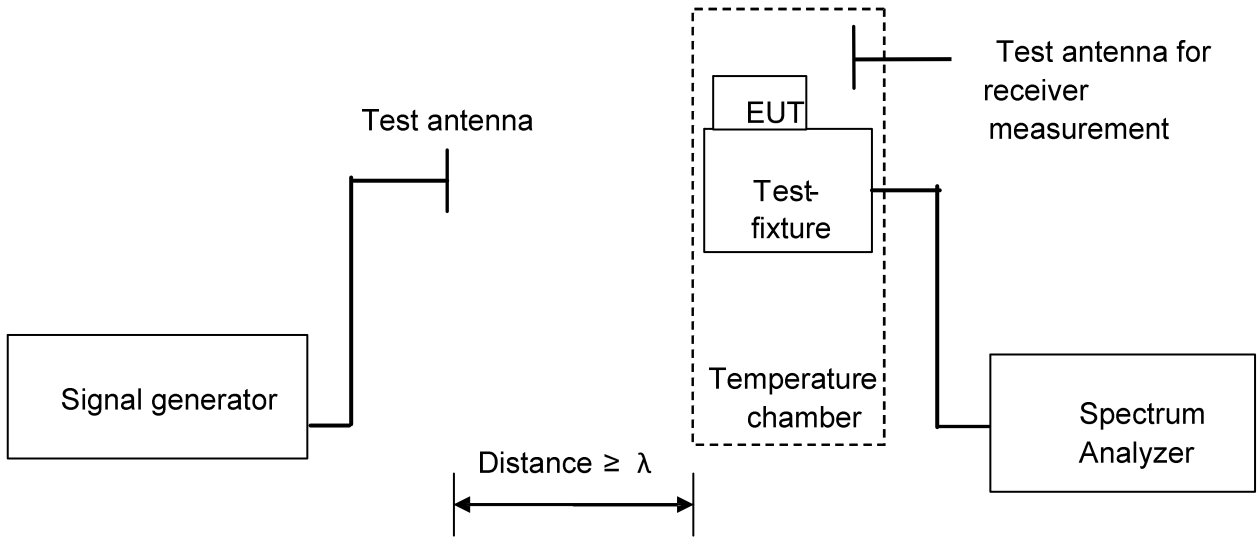

Figure 17: Example of a validation of test set-up with EUT in place

Step 3

In case of a battery operated EUT that is supplied by a temporary voltage feed as well as temporary signal- and control line, a decoupling filter shall be installed directly at the EUT in order to avoid parasitic, electromagnetic radiation. See figure 14.

In this step the signal generator and the transmit antenna are removed.

6.9.5 Climatic facilities for the use with a test fixture for measurements under extreme conditions

Requirements for climatic facilities:

- The required temperature performance level shall be such that the temperature radiant power of the internal walls and the thermal dissipation of the EUT in its enclosure become compensated.
- The facility shall have an air circulation feature with sufficient ventilation.
- It shall be calibrated in the middle of the empty volume.
- Calibration only needs to be done for the temperature conditions as set out in the relevant standards.

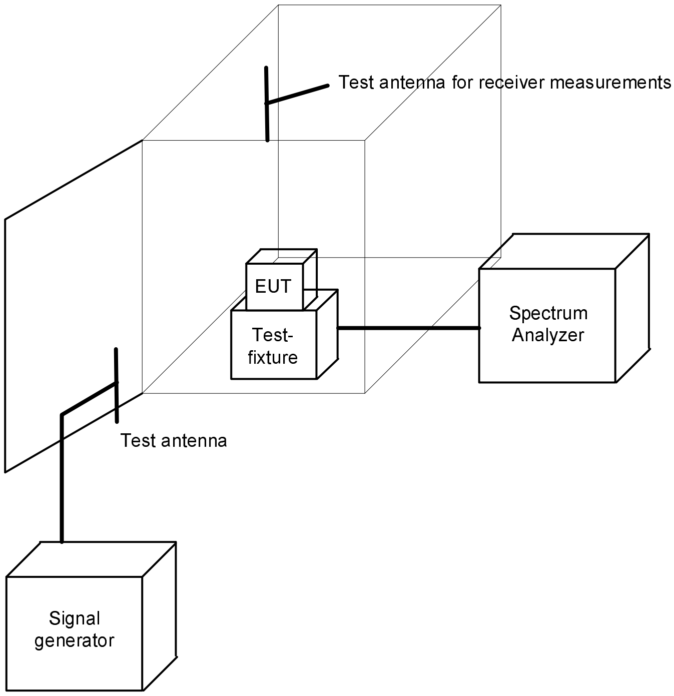

Figure 18: Example of a climatic facility test set-up (front view)

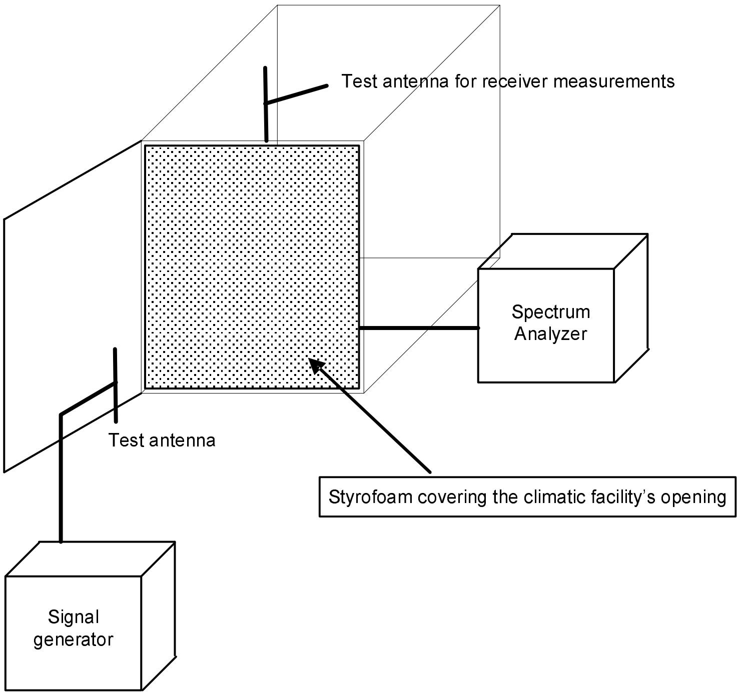

Figure 19: Example of a climatic facility test set-up (front view) with covered opening

6.9.6 Mode of use

The test fixture may be used to facilitate some of the transmitter and receiver measurements in the case of equipment having an integral antenna.

It is used particularly for the measurement of the radiated carrier power and usable sensitivity expressed as a field strength under extreme conditions. The measurements under extreme conditions are preceded by calibrated measurements. Furthermore a test fixture might be the most suitable equipment for duty cycle or modulation measurements.

6.9.7 Performance limitations

The coupling mechanism between the EUT and the test fixture is extremely complex since the two are placed physically and electrically very close together. This complexity makes any attempt at theoretically modelling a test fixture's performance not only very difficult but also time consuming and costly. In practice, therefore, modelling is seldom attempted. The direct consequence of this is that absolute measurements cannot be made in a test fixture and any measurement results have to be related, in some way, to results taken on a verified free field test site.

The usual way to relate the results is by a process, sometimes referred to as field equalization, in which the relevant parameter (effective radiated power, receiver sensitivity, etc.) is initially measured on a free field test site under normal conditions and then subsequently re-measured using only the test fixture (with the EUT installed) also under normal conditions. The difference (in dB) of the two results (received signal level for an effective radiated power test, output power from a signal generator for a sensitivity test) is termed the coupling factor of the test fixture and provides the link between all the results of EUT tests carried out in the test fixture and its performance on a verified free field test site. As a general rule, the coupling factor should not be greater than 20 dB.

To reiterate, this key limitation for a test fixture can be stated in two ways:

- only relative measurements can be made;
- absolute measurements cannot be made.

A further limitation to the use of a test fixture results from the unknown variation of the coupling factor with frequency. This variation cannot be relied upon to be linear over large bandwidths and this puts a limit on those tests which can be accurately carried out. As a result, emission tests are generally limited to the nominal frequencies (for which the performance of the test fixture has been verified) of low power devices for Effective Radiated Power (ERP) and frequency error tests. Occasionally, however, adjacent channel power is measured.

Similarly, receiver tests are normally limited to receiver sensitivity although, occasionally, co-channel rejection, adjacent channel selectivity, inter-modulation immunity and blocking are tested.

Ideally, all test fixtures should be verified and where EUT testing will be required over a frequency band, the verification procedure should be extended to include the frequencies at the band edges. In any case, routine verification, perhaps every six months, should be carried out as a means of detecting any deterioration or change in performance.

Local ambient signals can be problematic to measurements carried out in a test fixture, although very little uncertainty is introduced into transmitter tests, since EUT power levels will dominate. However, for receiver tests (i.e. sensitivity and various types of immunity testing) shielding from ambient signals may be required. Adequate shielding can be achieved by either using the test fixture within a metalized test chamber (e.g. climatic facility) or by enclosing it within a shielded room. In either case, one needs to be aware of the possible frequencies of resonance for these structures.

Only integral antenna devices are tested in a test fixture. For devices possessing either permanent or temporary external RF connectors, all testing is carried out using conducted methods.

6.10 RF cables

Radio equipment with external antenna connectors, antennas, measuring equipment connectors and other RF connectors are usually standardized with transfer impedances of 50 Ω (asymmetrical). When using RF cables it has to be ensured that these cables have a low loss. Compliance with the impedance level in the frequency range where the cable is intended to be used is also necessary.

When using coaxial cables for frequencies above 40 GHz attenuation features increase significantly and decrease of return loss due to mismatching caused by joints at RF connectors and impedance errors have to be considered. With a cable bore diameter of 2,40 mm, 1,85 mm or 1,0 mm the mechanic and electric stability of the cable are accordingly very low. The same applies to the corresponding connections.

Table 4: Types of RF cables

Connector System	Frequency
N	18 GHz
SMA	18 GHz (some up to 26 GHz)
3,50 mm	26,5 GHz
2,92 mm	40 GHz (some up to 46 GHz)
2,40 mm	50 GHz (some up to 60 GHz)
1,85 mm	65 GHz (some up to 75 GHz)
1,00 mm	110 GHz

6.11 RF waveguides

Wired signal transmission in the millimetre range is preferably realized by means of waveguides because they offer low attenuation and high reproducibility. Unlike coaxial cables, the frequency range in which waveguides can be used is limited also towards lower frequencies (highpass filter characteristics). Wave propagation in the waveguide is not possible below a certain cutoff frequency where attenuation of the waveguide is very high. Beyond a certain upper frequency limit, several wave propagation modes are possible so that the behaviour of the waveguide is no longer unambiguous. In the unambiguous range of a rectangular waveguide, only H10 waves are capable of propagation.

The dimensions of rectangular and circular waveguides are defined by international standards such as IEC 60153 [i.2] for various frequency ranges. These frequency ranges are also referred to as waveguide bands. They are designated using different capital letters depending on the standard. Table 5 provides an overview of the different waveguide bands together with the designations of the associated waveguides and flanges.

For rectangular waveguides, which are mostly used in measurements, harmonic mixers with matching flanges are available for extending the frequency coverage of measuring receivers.

Table 5: Waveguide bands and associated waveguides

Band	Frequency	Designations				Internal dimensions of waveguide		Designations of frequently used flanges		
	in GHz	MIL-W-85	EIA	153-IEC	RCSC (British)	in mm	in inches	MIL-F-3922	UG-XXX/U equivalent (reference)	Remarks
Ka	26,5 - 40,0	3-006	WR-28	R320	WG-22	7,11 x 3,56	0,280 x 0,140	54-006 68-002 67B-005	UG-559/U - UG-381/U	Rectangular Rectangular Round
Q	33,0 - 55,0	3-010	WR-22	R400	WG-23	5,69 x 2,84	0,224 x 0,112	67B-006	UG-383/U	Round
U	40,0 - 60,0	3-014	WR-19	R500	WG-24	4,78 x 2,388	0,188 x 0,094	67B-007	UG-383/U-M	Round
V	50,0 - 75,0	3-017	WR-15	R620	WG-25	3,759 x 1,879	0,148 x 0,074	67B-008	UG-385/U	Round
E	60,0 - 90,0	3-020	WR-12	R740	WG-26	3,099 x 1,549	0,122 x 0,061	67B-009	UG-387/U	Round
W	75,0 - 110,0	3-023	WR-10	R900	WG-27	2,540 x 1,270	0,100 x 0,050	67B-010	UG-383/U-M	Round

As waveguides are rigid, it is unpractical to set up connections between antenna and measuring receiver with waveguides. Either a waveguide transition to coaxial cable is used or - at higher frequencies - the harmonic mixer used for frequency extension of the measuring receiver is directly mounted at the antenna.

6.12 External harmonic mixers

6.12.1 Introduction

Measuring receivers (test receivers or spectrum analyzers) with coaxial input are commercially available up to 26,5 GHz to 67 GHz. The frequency range is extended from 26,5 / 67 GHz up to 100 GHz and beyond by means of external harmonic mixers. Harmonic mixers are used because the fundamental mixing commonly employed in the lower frequency range is too complex and expensive or required components such as preselectors are not available. Harmonic mixers are waveguide based and have a frequency range matching the waveguide bands. They must not be used outside these bands for calibrated measurements.

In harmonic mixers, a harmonic of the local oscillator (LO) is used for signal conversion to a lower intermediate frequency (IF). The advantage of this method is that the frequency range of the local oscillator may be much lower than with fundamental mixing, where the LO frequency must be of the same order (with low IF) or much higher (with high IF) than the input signal (RF). The harmonics are generated in the mixer because of its nonlinearity and are used for conversion. The signal converted to the IF is coupled out of the line which is also used for feeding the LO signal.

To obtain low conversion loss of the external mixer, the order of the harmonic used for converting the input signal should be as low as possible. For this, the frequency range of the local oscillator must be as high as possible. LO frequency ranges are for example 3 GHz to 6 GHz or 7 GHz to 15 GHz. IF frequencies are in the range from 320 MHz to about 700 MHz.

Because of the great frequency spacing between the LO and the IF signal, the two signals can be separated by means of a simple diplexer. The diplexer may be realized as part of the mixer or the spectrum analyzer, or as a separate component. Mixers with an integrated diplexer are also referred to as three-port mixers, mixers without diplexers as two-port mixers.

Coaxial cable connections to an external mixer (diplexer) shall be calibrated as well and in conjunction when calibrating the mixer and the measuring receiver. Those cables shall not be replaced in concrete measurements. In particular the cable length shall not be varied.

It shall be regarded that the mixer inputs are sufficiently insulated towards the antenna port with regard to the injected signal (mixed signal) so that the mixed signal, multiplied by the LO, is sufficiently absorbed.

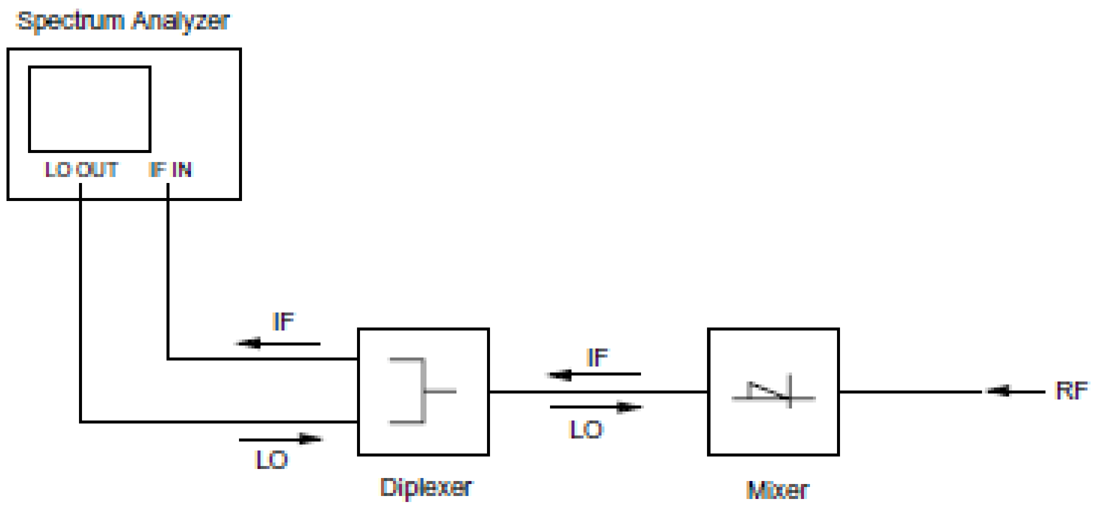

Figure 20: Set-up of measurement receiver, diplexer and mixer

6.12.2 Signal identification

A setup with Harmonic mixers without pre-selection displays always a pair of signals with a spacing of 2 x $f_{IF,}$ as there is no image suppression. For a modulated signal with a bandwidth of > 2 x f_{IF} both, wanted and image response overlap and cannot be separated any more.

Depending on the width of the analyzed frequency bands additional responses created from other harmonics may be displayed. In these cases it has to be determined with good engineering practice, which of the displayed responses are false responses. Signal identification techniques implemented in spectrum analyzers are based on the fact that only responses corresponding to the selected number of harmonic show a frequency spacing of 2 x $f_{IF.}$

This can be used for automated signal identification: Apart from the actual measurement sweep, in which the lower sideband is defined as "wanted", a reference sweep is performed. For the reference sweep, the frequency of the LO signal is tuned such that the user-selected harmonic of the LO signal (order m´) is shifted downwards by 2 x fIF relative to the measurement sweep.

Parameters which influence the signal identification routines are:

- Number of harmonic: the higher the harmonic number the more false responses will be created. A high LO frequency range which results in a lower harmonic number for a given frequency range is desirable.
- IF Frequency: The higher the IF frequency of the spectrum analyzer, the greater the spacing at which image frequency response is displayed on the frequency axis. For a single modulated or unmodulated input signal displayed on the frequency axis, an image-free range of 2 x f_{IF} is obtained around this signal in which no signal identification is necessary.

6.12.3 Conversion loss data and measurement uncertainty

Calibrated conversion loss data for harmonic mixers are given for a dedicated number of harmonic, IF frequency and LO power. They cannot be used for a different number of harmonic. It is equally essential that the LO level at the harmonic mixer matches the LO level for which the conversion loss data have been derived.

The above conditions adhered to a measurement uncertainty including the measuring receiver of < ±3 dB to 5 dB at the frequency of the calibration points can be expected, depending on the waveguide band. (Example 75 GHz to 110 GHz 3-port harmonic mixer: < 4,5 dB (K = 2, 5 to 45 °C)).

Harmonic mixers frequently have a low return loss (typ. 6 dB to 7 dB), which increases the measurement uncertainty. It is therefore expedient to insert an attenuator or isolator between the mixer and the antenna in order to improve measurement uncertainty. However, the insertion loss caused by such a component will reduce the sensitivity of the spectrum analyzer and mixer setup. This insertion loss has also to be taken into account for level measurements.

Mixers with integrated isolator are preferable, as they are already calibrated with the isolator included.

6.12.4 Preamplifier

Preamplifiers shall have asymmetric inputs and outputs with an impedance of 50 Ω. Preamplifier shall be sufficiently calibrated with regard to frequency response, amplification factor, linearity and compression. Should this not be obtainable, the amplification factor shall be determined at a certain frequency with a certain input power by substitution with a certain signal which is similarly defined as the original signal.

When using a preamplifier it shall be regarded that the amplifier has sufficient impulse response and that it is not overloaded with a too high input signal, which can lead to erroneous measurement results.

6.12.5 Wave Guide Attenuators

Due to the fact that external harmonic mixers can only be fed with low RF power it may be necessary to attenuate input powers in defined manner using wave guide attenuators. These attenuators should be calibrated and suitable to handle corresponding powers.

6.12.6 Measurement hints

To obtain accurate and reproducible results, the following points should be observed:

- A low-loss cable with a flat frequency response should be used for feeding the LO signal to the mixer. The conversion loss of the mixer is normally specified for a defined LO level. It is therefore important to maintain this level at the LO port of the mixer in order to achieve the desired accuracy. This is especially essential if the antenna/ mixer combination is located away from the measuring receiver.

NOTE: The term "accuracy" is defined, in relation to the measured value, in clause 4.1.1 of TR 102 273 [5].

- In level correction on the spectrum analyzer, the insertion loss of the cable used for tapping the IF signal is to be taken into account.
- If an external diplexer is used for connecting a two-port mixer, the insertion loss of the IF path of the diplexer is to be taken into account in level correction on the spectrum analyzer.

6.13 Measuring receiver

The term "measuring receiver" refers to a frequency-selective voltmeter or a spectrum analyser. An RMS detector is used if not defined otherwise for a specific measurement. The measurement bandwidth of the measuring receiver shall, where possible, be according to CISPR 16 [1], [2] and [3]. In order to obtain the required sensitivity, a narrower measurement bandwidth may be necessary, and in such cases, this shall be stated in the test report form. The bandwidth of the measuring receiver shall be as given in table 6.

Table 6: Reference bandwidth for the measurement receiver

Frequency range: (f)	Measuring receiver bandwidth
f < 150 kHz	200 Hz or 300 Hz
150 kHz ≤ f < 25 MHz	9 kHz or 10 kHz
25 MHz ≤ f ≤ 1 000 MHz	100 kHz or 120 kHz
f > 1 000 MHz	1 MHz

In case of a narrower measurement bandwidth was used, the following conversion formula has to be applied:

$$B = A + 10 \log \frac{BWref}{BW_{MEASURED}}$$

Where:

- A is the value at the narrower measurement bandwidth;
- B is the value referred to the reference bandwidth; or

Use the measured value, A, directly if the measured spectrum is a discrete spectral line. (A discrete spectrum line is defined as a narrow peak with a level of at least 6 dB above the average level inside the measurement bandwidth.)

When using a spectrum analyser, good engineering practice shall avoid overloading of the equipment which can lead to false test results.

7 Measurement uncertainty

7.1 Introduction

The uncertainty of the result of a measurement is expressed as standard deviation.

Measurement uncertainty of a test site for determination of electromagnetic radiation power or field strength can be determined as a whole.

If the uncertainties of all single components that compose the test site are added, preliminary consideration may be useful on one hand. On the other hand the problems with impedance matching of single components shall be regarded.

Another step would be quantifying all uncertainty components by suitable methods.

A first quantitative estimation can be useful for showing that some single components are "insignificant" and require no closer determination. For most instances a practical definition of an "insignificant" component can be found in clause 6.6 of EA-4/16 [10] which states that not all the uncertainty sources identified during an uncertainty evaluation will make a significant contribution to the combined uncertainty.

In deciding whether an uncertainty contribution can be neglected, it is important to consider:

- The relative sizes of the largest and the smaller contributions. For example, a contribution that is one fifth of the largest contribution will contribute at most 2 % of the combined standard uncertainty.
- The effect on the reported uncertainty. It is imprudent to make approximations that materially affect the reported uncertainty or the interpretation of the result.
- The degree of rigour justified for the uncertainty evaluation, taking into account the client and regulatory and other external requirements identified, for example, during contract review.

7.1.1 Uncertainty contributions specific to an Open Area Test Site

Open Area Test Site performance is dependent on many factors such as the size and shape of the ground plane, its surface material and roughness, edge termination, dielectric coverings, environmental conditions, weather protection, the size of the EUT, the type of test being carried out, the required frequency range, etc.

7.1.2 Uncertainty contributions specific to an Anechoic Room with a Ground Plane

A typical Anechoic Chamber with a Ground Plane comprises three main components:

- a metallic shield;
- radio absorbing material;
- a highly reflective ground plane.

Whilst each of these components is included to improve the quality of the testing environment within the chamber, each has negative effects as well.

7.1.3 Uncertainty contributions specific to an Anechoic Room

A typical Anechoic Chamber comprises two main components:

- a metallic shield;
- radio absorbing material.

Whilst each component is included to improve the quality of the testing environment within the chamber, each has negative effects as well.

7.2 Measurement results

Measurement results related to RF power or field strength consists of a measured value and the measurement uncertainty. Measurement uncertainty is established in retracing the uncertainties to comparison standards that are public domain. The measurement results with the related measurement uncertainty as well as the used measurement equipment with indication of calibration validity shall always be indicated in test reports.

7.3 Measurement efficiency

The most accurate radiated measurement method is the substitution method. But when a lot of reading points have to be observed it becomes very time-consuming. If only proof of compliance with limit values is required and if the test results are well below the limits it is recommended to use the radiated power measurement based on site attenuation.

An assessment of the radiated power with determination of the theoretical free-space path loss only cannot be calibrated since environmental effects are not taken into account.

7.4 Maximum expanded measurement uncertainty

In most ETSI radio equipment standards a table of maximum acceptable expanded measurement uncertainty is included as a normative requirement. The table generally contains a list of the required measurement methods and their associated expanded measurement uncertainty.

The purpose of the table is to ensure that the expanded measurement uncertainty is controlled and that a wide variation of measured results between test laboratories is minimized. This approach also assists the process of laboratory accreditation for testing to the standard.

In discussion with test laboratories, they indicated that it would be extremely useful to associate directly the specification limit given in the standard with the required maximum allowable expanded measurement uncertainty for the measured value.

As frequency ranges increase it may be difficult to conclude a maximum allowable value for the expanded measurement uncertainty due to lack of knowledge of the new methods of test and determining the uncertainty components:

- The commercially available calibration capability is limited to around 65 GHz. Thus no such possibility is freely available on the market above that limit. As a consequence measurement results above 65 GHz of different labs are not fully comparable since the equipment will not be calibrated for the needed operational range and also for radiated unwanted emission measurements above the operational range.
- The expanded measurement uncertainty of measurements in the range between 65 GHz and 100 GHz will be clearly above the values valid for below 65 GHz. Precise values of expanded measurement uncertainty require calibration, and there are limitations as mentioned above.
- In general it has to be mentioned that these values become the higher the frequency will become the more a guideline.
- Starting from around 65 GHz the limits of coaxial systems are reached and the frontend has to switch to wave guide based technologies adding an additional attenuation and also decreasing the sensitivity. Commercially available analyzers can only measure up to around 63 GHz, thus making the use of external mixers unavoidable.

Guidance is provided in TS 103 051 [i.1] that presents an evaluation of maximum acceptable measurement uncertainty for Radio Frequency (RF) electromagnetic field (emf) measurements for the frequency range from 30 MHz to 100 GHz for inclusion within ETSI documents on radio products used for compliance testing.

For the test methods, according to TS 103 051 [i.1] the expanded measurement uncertainty figures should be calculated according to the methods described in TR 100 028 [4] and should include an expansion factor (coverage factor) k = 1,96 which provides a confidence levels of 95 % in cases where the distributions characterising the actual measurement uncertainties are normal (Gaussian)).

Annex A (informative): Bibliography

JCGM 200:2008: "International vocabulary of metrology - Basic and general concepts and associated terms (VIM)".

History

Document history		
V1.1.1	March 2011	Publication