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Foreword

This ETSI Technical Report (ETR) has been produced by the Electromagnetic compatibility and Radio spectrum Matters (ERM) Technical Committee of the European Telecommunications Standards Institute (ETSI).

ETRs are informative documents resulting from ETSI studies which are not appropriate for European Telecommunication Standard (ETS) or Interim European Telecommunication Standard (I-ETS) status. An ETR may be used to publish material which is either of an informative nature, relating to the use or the application of ETSs or I-ETSs, or which is immature and not yet suitable for formal adoption as an ETS or an I-ETS.

The present document is part 2 of a multi-part Technical Report (ETR) covering Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement of radiated methods of measurement (using test sites) and evaluation of the corresponding measurement uncertainties, as identified below:

Part 1-1: "Uncertainties in the measurement of mobile radio equipment characteristics; Sub-part 1: Introduction";

Part 1-2: "Uncertainties in the measurement of mobile radio equipment characteristics; Sub-part 2: Examples and annexes";

Part 2: "Anechoic chamber";

Part 3: "Anechoic chamber with a ground plane";

Part 4: "Open area test site";

Part 5: "Striplines";

Part 6: "Test fixtures";

Part 7: "Artificial human beings".

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1 Scope

This ETR covers the methods of radiated measurements on mobile radio equipment in anechoic chambers and applies to the assessment of the associated measurement uncertainties.

This ETR also provides the methods for evaluation and calculation of the measurement uncertainties for each of the measured parameters and the required corrections for measurement conditions and results.

2 References

Within this ETR the following references apply:

[1] "ANSI C63.5-(1988): "Electromagnetic Compatibility-Radiated Emission Measurements in Electromagnetic Interference (EMI) Control - Calibration of Antennas".

[2] "Antenna theory", C. Balanis, J. E. Wiley 1982.

[3] "Calculation of site attenuation from antenna factors" A. A. Smith Jr, RF German and J B Pate. IEEE transactions EMC. Vol. EMC 24 pp 301-316 Aug 1982.

[4] CCITT Recommendation O.153: "Basic parameters for the measurement of error performance at bit rates below the primary rate".

[5] CCITT Recommendation O.41: "Psophometer for use on telephone-type circuits".

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

[7] EN 50147-2 (1996): "Anechoic chambers -- Part 2: Alternative test site suitability with respect to site attenuation".

[8] ETR 273-1-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement of radiated methods of measurement (using test sites) and evaluation of the corresponding measurement uncertainties; Part 1: Uncertainties in the measurement of mobile radio equipment characteristics; Sub-part 1: Introduction".

[9] ETR 273-1-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement of radiated methods of measurement (using test sites) and evaluation of the corresponding measurement uncertainties; Part 1: Uncertainties in the measurement of mobile radio equipment characteristics; Sub-part 2: Examples and annexes".

[10] "The gain resistance product of the half-wave dipole", W. Scott Bennet Proceedings of IEEE vol. 72 No. 2 Dec 1984 pp 1824-1826.

[11] The new IEEE standard dictionary of electrical and electronic terms. Fifth edition, IEEE Piscataway, NJ USA 1993.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of this ETR, the following definitions apply:

Audio Frequency (AF) load: Normally a resistor of sufficient power rating to accept the maximum audio output power from the EUT. The value of the resistor is normally that stated by the manufacturer and is normally the impedance of the audio transducer at 1 000 Hz.

NOTE 1: In some cases it may be necessary to place an isolating transformer between the output terminals of the receiver under test and the load.

A-M1: A test modulation consisting of a 1 000 Hz tone at a level which produces a deviation of 12 % of the channel separation.

A-M2: A test modulation consisting of a 1 250 Hz tone at a level which produces a deviation of 12 % of the channel separation.

A-M3: A test modulation consisting of a 400 Hz tone at a level which produces a deviation of 12 % of the channel separation. This signal is used as an unwanted signal for analogue and digital measurements.

AF termination: Any connection other than the audio frequency load which may be required for the purpose of testing the receiver. (i.e. in a case where it is required that the bit stream be measured, the connection may be made, via a suitable interface, to the discriminator of the receiver under test).

NOTE 2: The termination device is normally agreed between the manufacturer and the testing authority and details included in the test report. If special equipment is required then it is normally provided by the manufacturer.

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. When properly applied to the meter reading of the measuring instrument, yields the electric field strength in V/m or the magnetic field strength in A/m.

antenna gain: The 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: The ratio of the number of bits in error to the total number of bits.

combining network: A multipole network allowing the addition of two or more test signals produced by different sources for connection to a receiver input.

NOTE 3: Sources of test signals are normally connected in such a way that the impedance presented to the receiver is 50 Ω. The combining networks are designed so that effects of any intermodulation products and noise produced in the signal generators are negligible.

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

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

directivity: The 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).

DM-0: A test modulation consisting of a signal representing an infinite series of "0" bits.

DM-1: A test modulation consisting of a signal representing an infinite series of "1" bits.

DM-2: A test modulation consisting of a signal representing a pseudorandom bit sequence of at least 511 bits in accordance with CCITT Recommendation O.153 [4].

DM-3: A test signal agreed between the testing authority and the manufacturer in the cases where it is not possible to measure a bit stream or if selective messages are used and are generated or decoded within an equipment.

NOTE 4: The agreed test signal may be formatted and may contain error detection and correction. Details of the test signal are be supplied in the test report.

duplex filter: A 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): The result of a measurement minus the true value of the measurand.

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

estimated standard deviation: From a sample of n results of a measurement the estimated standard deviation is given by the formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

x_i being the i^{th} result of measurement (i = 1,2,3, ...,n) and $\bar{x}$ the arithmetic mean of the n results considered.

A practical form of this formula is:

$$\sigma = \sqrt{\frac{Y - \frac{X^2}{n}}{n-1}}$$

Where X is the sum of the measured values and Y is the sum of the squares of the measured values.

extreme test conditions: Conditions defined in terms of temperature and supply voltage. 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): The indication of a measuring instrument minus the (conventional) true value.

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

free Space: A region free of obstructions and characterized by the constitutive parameters of a vacuum.

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

impedance (wave): The 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: A 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 manufacturer states the maximum time that the equipment is intended to transmit and the necessary standby period before repeating a transmit period.

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

limited Frequency Range: The limited frequency range is a specified smaller frequency range within the full frequency range over which the measurement is made.

NOTE 5: The details of the calculation of the limited frequency range are normally given in the relevant testing standard.

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

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

measurement repeatability: The 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: The 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.

measurand: A quantity subjected to measurement.

noise gradient of EUT: A function characterizing the relationship between the RF input signal level and the performance of the EUT, e.g., 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: The declared voltage or any of the declared voltages for which the equipment was designed.

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

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

psophometric weighting network: As described in CCITT Recommendation O.41 [5].

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): An attribute of a phenomenon or a body which may be distinguished qualitatively and determined quantitatively.

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

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

shielded enclosure: A 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: The minimum standard modulated carrier-signal input required to produce a specified SINAD ratio at the receiver output.

stochastic (random) variable: A variable whose value is not exactly known, but is characterized by a distribution or probability function, or a mean value and a standard deviation (e.g. a measurand and the related measurement uncertainty).

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

test modulation: The 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: A circuit or mechanism to trigger the oscilloscope timebase at the required instant. It may control the transmit function or inversely receive an appropriate command from the transmitter.

uncertainty (random): A component of the uncertainty of measurement which, in the course of a number of measurements of the same measurand, varies in an unpredictable way.

uncertainty (systematic): A component of the uncertainty of measurement which, in the course of a number of measurements of the same measurand remains constant or varies in a predictable way.

uncertainty (limits of uncertainty of a measuring instrument): The extreme values of uncertainty permitted by specifications, regulations etc. for a given measuring instrument.

NOTE 6: This term is also known as "tolerance".

uncertainty (standard): The representation of each individual uncertainty component that contributes to the overall measurement uncertainty by an estimated standard deviation is termed the standard uncertainty.

uncertainty (combined standard): The combined standard uncertainty of a measurement is calculated by combining the standard uncertainties for each of the individual contributions identified.

NOTE 7: This combination is carried out by applying the Root Sum of Squares (RSS) method under the assumption that all contributions are stochastic i.e. independent of each other.

uncertainty (expanded): The combined standard uncertainty is multiplied by a constant to give the expanded uncertainty limits.

upper specified AF limit: The maximum audio frequency of the audio pass-band. It is dependent on the channel separation.

wanted signal level: For conducted measurements Pa level of +6 dBµV emf referred to the receiver input under normal test conditions. Under *extreme test conditions* the value is +12 dBµV emf.

NOTE 8: 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 this ETR, the following symbols apply:

β	2π/λ (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 polarisation) (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	2π/λ
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
λ	wavelength (m)

p	power level value
$Pe_{(n)}$	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	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
r	indicates rectangular distribution
SNR_{b*}	Signal to noise ratio at a specific BER
SNR_b	Signal to noise ratio per bit
T_A	antenna temperature (° Kelvin)
u	indicates U-distribution
U	the expanded uncertainty corresponding to a confidence level of x %: $U = k \times u_c$
u_c	the combined standard uncertainty
u_i	general type A standard uncertainty
u_{i01}	random uncertainty
u_j	general type B uncertainty
u_{j01}	reflectivity of absorbing material: EUT to the test antenna
u_{j02}	reflectivity of absorbing material: substitution or measuring antenna to the test antenna
u_{j03}	reflectivity of absorbing material: transmitting antenna to the receiving antenna
u_{j04}	mutual coupling: EUT to its images in the absorbing material
u_{j05}	mutual coupling: de-tuning effect of the absorbing material on the EUT
u_{j06}	mutual coupling: substitution, measuring or test antenna to its image in the absorbing material
u_{j07}	mutual coupling: transmitting or receiving antenna to its image in the absorbing material
u_{j08}	mutual coupling: amplitude effect of the test antenna on the EUT
u_{j09}	mutual coupling: de-tuning effect of the test antenna on the EUT
u_{j10}	mutual coupling: transmitting antenna to the receiving antenna
u_{j11}	mutual coupling: substitution or measuring antenna to the test antenna
u_{j12}	mutual coupling: interpolation of mutual coupling and mismatch loss correction factors
u_{j13}	mutual coupling: EUT to its image in the ground plane
u_{j14}	mutual coupling: substitution, measuring or test antenna to its image in the ground plane
u_{j15}	mutual coupling: transmitting or receiving antenna to its image in the ground plane
u_{j16}	range length
u_{j17}	correction: off boresight angle in the elevation plane
u_{j18}	correction: measurement distance
u_{j19}	cable factor
u_{j20}	position of the phase centre: within the EUT volume

u_{j21}	positioning of the phase centre: within the EUT over the axis of rotation of the turntable
u_{j22}	position of the phase centre: measuring, substitution, receiving, transmitting or test antenna
u_{j23}	position of the phase centre: LPDA
u_{j24}	Stripline: mutual coupling of the EUT to its images in the plates
u_{j25}	Stripline: mutual coupling of the 3-axis probe to its image in the plates
u_{j26}	Stripline: characteristic impedance
u_{j27}	Stripline: non-planar nature of the field distribution
u_{j28}	Stripline: field strength measurement as determined by the 3-axis probe
u_{j29}	Stripline: transform factor
u_{j30}	Stripline: interpolation of values for the transform factor
u_{j31}	Stripline: antenna factor of the monopole
u_{j32}	Stripline: correction factor for the size of the EUT
u_{j33}	Stripline: influence of site effects
u_{j34}	ambient effect
u_{j35}	mismatch: direct attenuation measurement
u_{j36}	mismatch: transmitting part
u_{j37}	mismatch: receiving part
u_{j38}	signal generator: absolute output level
u_{j39}	signal generator: output level stability
u_{j40}	insertion loss: attenuator
u_{j41}	insertion loss: cable
u_{j42}	insertion loss: adapter
u_{j43}	insertion loss: antenna balun
u_{j44}	antenna: antenna factor of the transmitting, receiving or measuring antenna
u_{j45}	antenna: gain of the test or substitution antenna
u_{j46}	antenna: tuning
u_{j47}	receiving device: absolute level
u_{j48}	receiving device: linearity
u_{j49}	receiving device: power measuring receiver
u_{j50}	EUT: influence of the ambient temperature on the ERP of the carrier
u_{j51}	EUT: influence of the ambient temperature on the spurious emission level
u_{j52}	EUT: degradation measurement
u_{j53}	EUT: influence of setting the power supply on the ERP of the carrier
u_{j54}	EUT: influence of setting the power supply on the spurious emission level
u_{j55}	EUT: mutual coupling to the power leads
u_{j56}	frequency counter: absolute reading
u_{j57}	frequency counter: estimating the average reading
u_{j58}	Salty man/Salty-lite: human simulation
u_{j59}	Salty man/Salty-lite: field enhancement and de-tuning of the EUT
u_{j60}	Test Fixture: effect on the EUT
u_{j61}	Test Fixture: climatic facility effect on the EUT
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 this ETR, the following abbreviations apply:

AF	Audio Frequency
BER	Bit Error Ratio
CD	Citizen's Band
DELT	
DM-0	A test modulation consisting of a signal representing an infinite series of "0" bits
DM-1	A test modulation consisting of a signal representing an infinite series of "1" bits
DM-2	A test modulation consisting of a signal representing a pseudorandom bit sequence of at least 511 bits in accordance with CCITT Recommendation O.153 [4]
DM-3	A test signal should be agreed between the testing authority and the manufacturer in the cases where it is not possible to measure a bit stream or if selective messages are used and are generated or decoded within an equipment

NOTE: The agreed test signal may be formatted and may contain error detection and correction. Details of the test signal are be supplied in the test report.

emf	Electromotive force
EUT	Equipment Under Test
FSK	Frequency Shift Keying
GMSK	Gaussian Minimum Shift Keying
GSM	Global System for Mobile telecommunication (Pan European digital telecommunication system)
IF	Intermediate frequency
LPDA	Log Periodic Dipole Antenna
m	measured
NaCl	Sodium chloride
NSA	Normalized Site Attenuation
r	indicates rectangular distribution
RF	Radio Frequency
rms	root mean square
RSS	Root-Sum-of-the-Squares
TEM	Transverse Electro-Magnetic
u	indicates U-distribution
VSWR	Voltage Standing Wave Ratio

4 Introduction

An anechoic chamber 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 ambients. The chamber contains an antenna support at one end and a turntable at the other. A typical anechoic chamber is shown in figure 1 with dipole antennas at both ends.

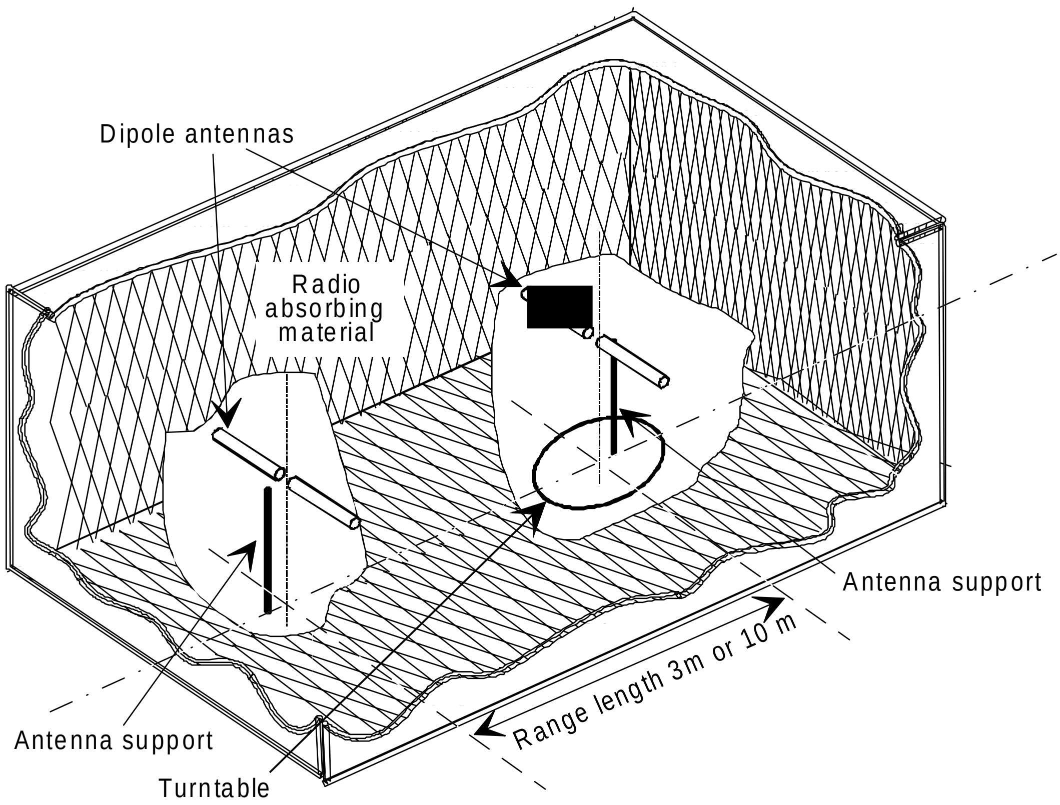


Figure 1: A typical anechoic chamber

The chamber shielding and radio absorbing material work together to provide a controlled environment for testing purposes. This type of test chamber 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 chamber 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 an anechoic chamber. 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 chamber, with acceptability being decided on the basis of the maximum difference between the two.

5 Uncertainty contributions specific to an anechoic chamber

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. Below, some positive effects are mentioned as a brief introduction to a discussion of the negative effects and their impact on measurement uncertainty.

5.1 Effects of the metal shielding

The benefits of shielding a testing area can be seen by considering the situation on a typical open area test site where ambient RF interference can add considerable uncertainty to the measurements. Such RF ambient signals can be continuous sources e.g. commercial radio and television, link services, navigation etc. or intermittent ones e.g. CB, emergency services, DECT, GSM, paging systems, machinery and a variety of others. The interference can be either narrowband or broadband.

The anechoic chamber overcomes these problems by the provision of a shielded enclosure. A shielded enclosure is defined as any structure that protects its interior from the effects of an exterior electric or magnetic field, or conversely, protects the surrounding environment from the effects of an interior field. The shielding is normally provided by metal panels with continuous electrical contact between them and any opening provided in the shield (e.g. doors and breakout panels).

Further advantages of the shield are protection from the weather and the general degradation effects it can have.

5.1.1 Resonances

Any metal shield will act as a reflecting surface and grouping six of them together to form a metal box makes it possible for the chamber to act like a resonant waveguide cavity. Whilst these resonance effects tend to be narrowband, their peak magnitudes can be high, resulting in a significant disruption of the desired field distribution.

A resonant waveguide cavity mode can, in theory, be excited at any frequency which satisfies the following formula:

$$f = 150\sqrt{\left(\frac{x}{l}\right)^2 + \left(\frac{y}{b}\right)^2 + \left(\frac{z}{h}\right)^2}\ \text{MHz}$$

where l, b and h are respectively the length, breadth and height of the chamber in metres and x, y and z are mode numbers of which only one is allowed to be zero at any time. As an example, the lowest frequency at which a resonance could occur in a facility which measures 5 m by 5 m by 7 m is 36,87 MHz.

Caution should be exercised whenever measurements are attempted close to any frequencies predicted by this formula, particularly for the lowest values, for which the absorber might offer poor performance. To improve confidence in the chamber, these lower calculated frequencies could be included in the verification procedure.

5.1.2 Imaging of antennas (or an EUT)

The shield will have a significant impact on the overall performance of the chamber if it is not adequately "masked" from the test volume by the absorbing material i.e. if the absorbing material has inadequate absorption characteristics.

For example, in the extreme case of 0 dB return loss from the absorbing materials (i.e. zero absorption/perfect reflection) an antenna (or EUT) will "see" an image of itself in the end wall close behind, the two side walls, the ceiling, the floor and, to a lesser extent, the far end wall (see figure 2).

In this multi-image environment, the one driven (real) antenna is, in effect, powering a seven element array (of which it is one). Major changes result to all of the antenna's (or the EUT's) electrical characteristics such as input impedance, gain and radiation pattern.

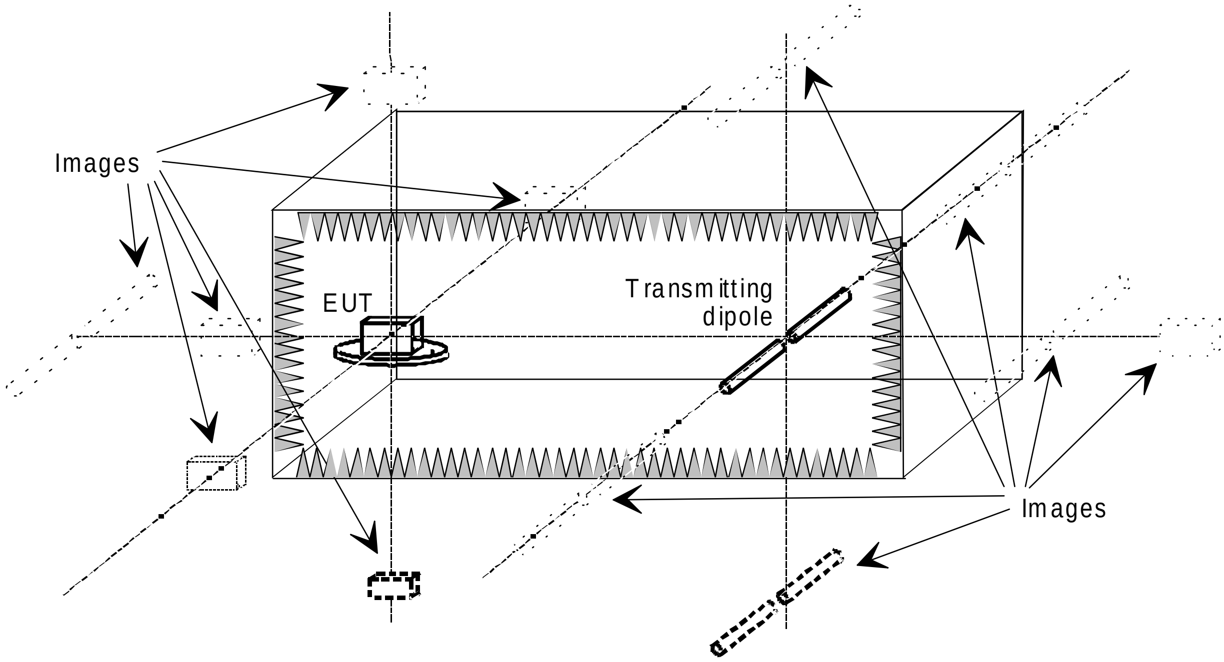


Figure 2: Imaging in the shielded enclosure

Whilst no chamber would be used at any frequency for which the absorbing material performs so badly as to appear "invisible", this example illustrates that any finite value of reflectivity will produce this imaging to some extent.

Good absorption (low reflectivity) will minimize all internal reflections, whereas poor absorption (high reflectivity) will not only produce imaging of the antennas (or the EUT), but can also contribute numerous high amplitude reflections.

5.2 Effects of the radio absorbing materials

5.2.1 Introduction

As discussed in subclause 5.1.2 the absorbing material plays a critical role in the chamber's performance. Absorption is the irreversible conversion of the energy of an electromagnetic wave into another form of energy as a result of wave interaction with matter [11] (i.e. it gets hot). The efficiency with which the material absorbs energy is determined by the absorption coefficient. This is defined as the ratio of the energy absorbed by the surface to the energy incident upon it [11]. It is more usual, however, for the reflectivity (i.e. return loss) of an absorbing material to be quoted rather than its absorption, the assumption being that any incident power not reflected is absorbed.

Different types of RF absorbers are available (see figure 3). They all absorb radiated energy to a greater or lesser extent, but possess different mechanical and electrical properties making certain types more suitable for some applications than others.

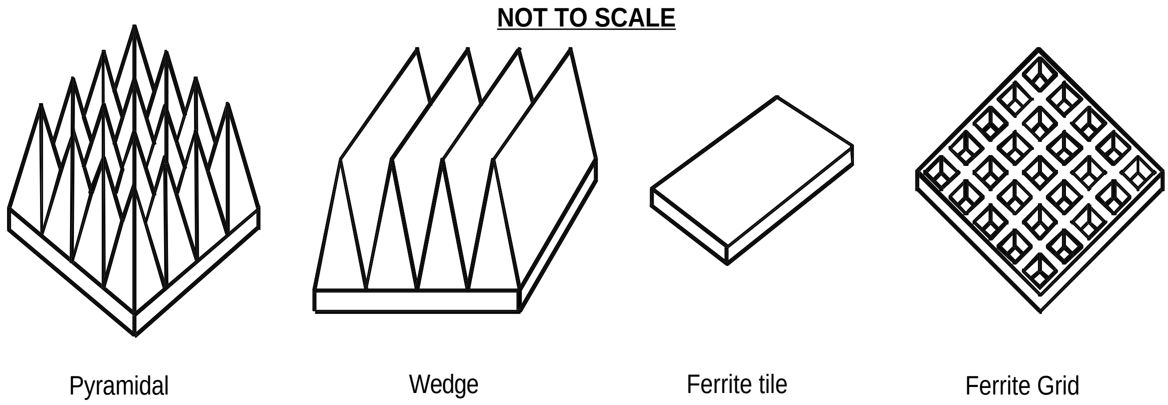


Figure 3: Typical RF absorbers

A review of commonly available types is now given.

5.2.2 Pyramidal absorbers

This type of absorber is manufactured from polyurethane foam impregnated with carbon, and moulded into a pyramidal shape (see figure 3). This shape provides inherently wide bandwidth, small polarization dependence and gives reasonably wide angular coverage.

Pyramidal absorbers behave as lossy, tapered transitions, ranging from low impedance at the base to 377 Ω at the tip (to match the impedance of free space). They work on the principle that if all of the energy is converted to heat before the base is reached, there is nothing to reflect from the shield.

A line, drawn from the centre of the base through the centre of the tip of the pyramid is termed the normal angle of incidence (0°) and the pyramidal shape maximizes the absorber performance at this angle of incidence. As the angle of incidence increases, however, the return loss degrades, as illustrated in figure 4 for 50°, 60° and 70° angles against absorber thickness.

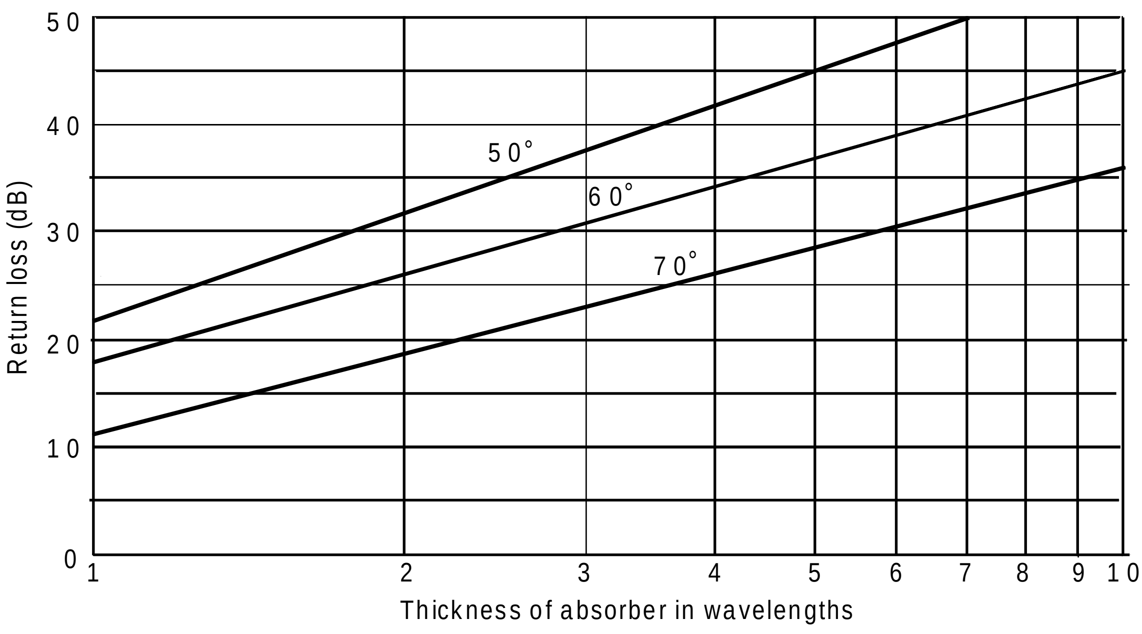


Figure 4: Typical return loss of pyramidal absorber at various incidence angles

This absorption characteristic leads to large reflection coefficients at large angles of incidence where the incident radio energy approaches broadside to the side faces of the pyramids. The reflection is primarily due to impedance mismatch between the incident wave and the absorber impedance taper.

The actual performance varies according to the degree of carbon loading and the shape and size of the cones. Its effectiveness in suppressing surface reflections is mainly a function of the cone height to wavelength ratio, the absorption improving as this ratio increases (see figure 5).

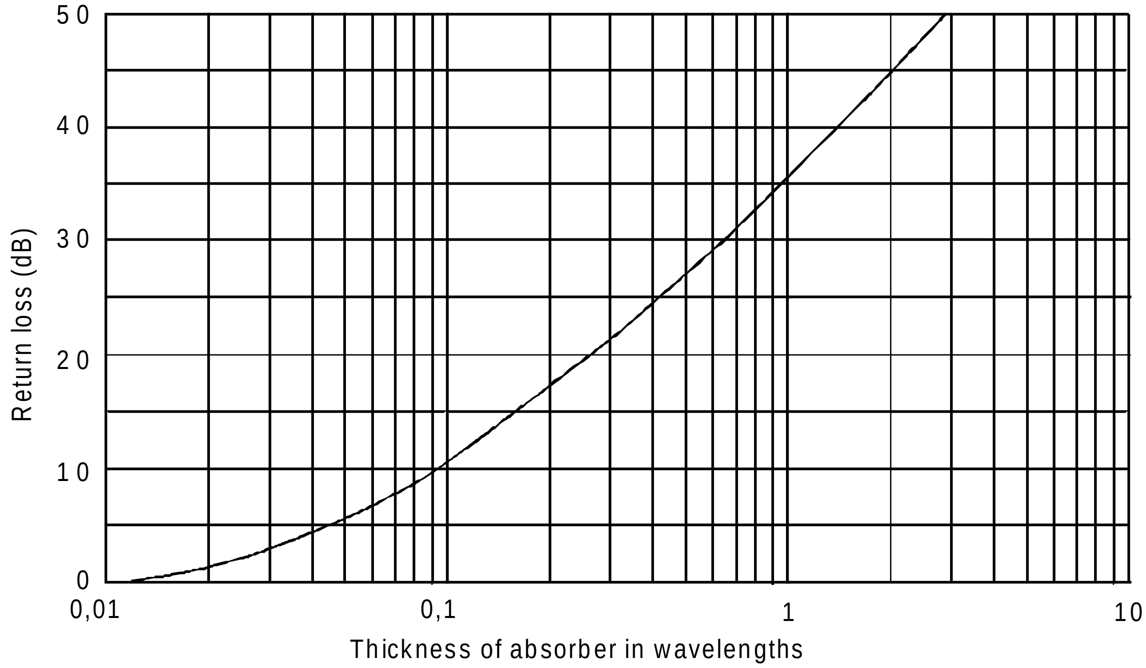


Figure 5: Typical return loss of pyramidal absorber at normal incidence

Larger cones therefore, have better low frequency performance e.g. 0,6 m length cones can only be used effectively down to about 120 MHz, whereas, for comparable performance, 1,778 m cones can be used effectively down to about 40 MHz. This improved performance can, however, only be attained at significantly increased cost and reduction in space efficiency (see table 1).

The high frequency performance of the pyramidal absorbers seems unlimited (see figure 5), but this is not the case. In practice, it is limited by resonant effects of the spacing between the peaks of the pyramids, absorber layout pattern and surface finish of the absorber in general. It is unreasonable to assume any absorber will give more than 50 dB return loss. In some chambers, mixed size pyramids are used to randomize the absorber pattern to improve its high frequency performance with only minimum degradation at the lower frequencies.

Flammability, space inefficiency and performance degradation over time caused by drooping under their own weight, breaking of the absorber tips and rounding of the valleys are major disadvantages of this type of absorber. However, a hollow cone version is available which reduces the overall weight and improves the mechanical stability. Flame retarding types are also available, but space inefficiency and "fragility" remain major problems with this type of absorber.

5.2.3 Wedge absorbers

Wedge absorbers (see figure 3), are a variation of the polyurethane pyramidal foam type, which tends to overcome the degradation of reflectivity with increasing angle of incidence, but at some performance cost.

This improvement is only for cases where the incident wave direction is parallel to the ridge of the wedge as no broadside presents itself at off normal angles as is the case with pyramidal absorbers.

Disadvantages of this type of absorber are degraded performance compared to pyramidal types at normal incidence and when used with the ridge perpendicular to the incident wave.

These effects make wedge absorbers more suitable for use in chambers with range lengths of 10 m or more where they are used to good advantage in the middle sections of the ceilings, floor and side walls.

5.2.4 Ferrite tiles

Ferrite is a ferromagnetic ceramic material. Its susceptibility and permeability are dependant on the field strength and magnetization curves (which have hysterisis). Its magnetic characteristics can be affected by pressure, temperature, field strength, frequency and time. Its mechanical and electromagnetic characteristics depend heavily on the sintering process used to form the ferrite. It is hard (physically), brittle (as are all ceramics) and will chip and break if handled roughly.

Ferrite tiles are thin, flat, ceramic blocks typically 15 cm by 8 cm by 1 cm thick (see figure 3). Both thickness and composition of the ferrite material affect their absorption performance. In practice, their layout is also very critical as small air gaps between adjacent tiles can considerably degrade performance at the lowest frequencies (30 to 100 MHz). However, when properly installed this is the frequency range for which they give the most benefit over pyramidal foam absorbers. They are generally manufactured to give about 15 to 20 dB return loss at 30 MHz (see figure 6).

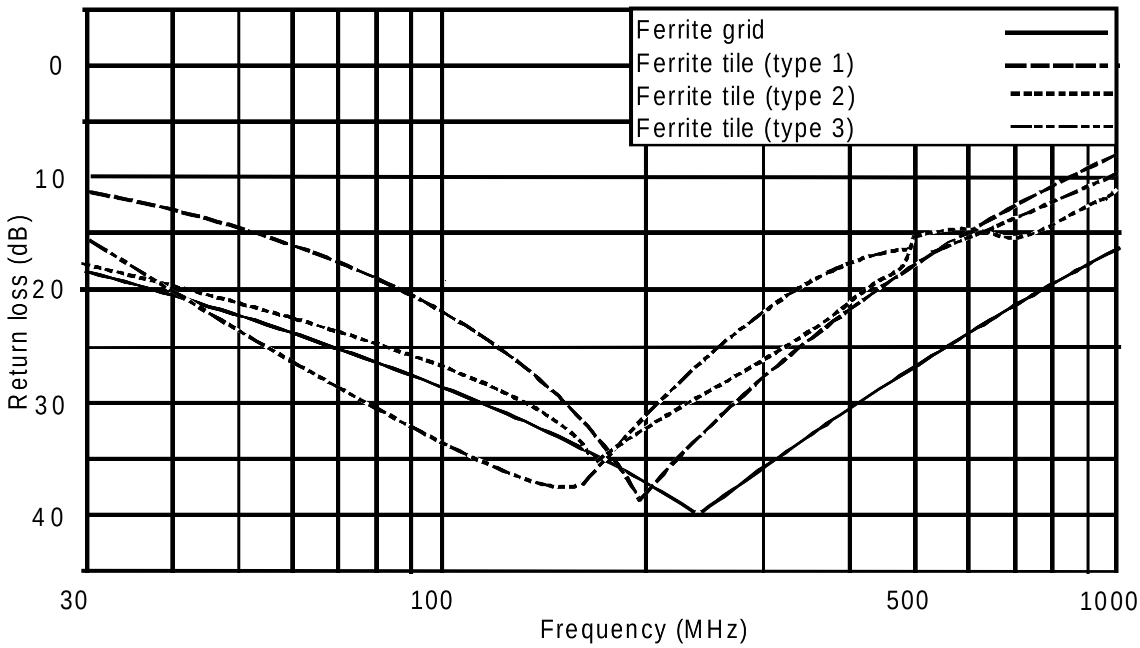


Figure 6: Normal incidence return loss variation of three different designs of ferrite tile and a ferrite grid against frequency

Their main advantages are that they are thin (typically 1 cm) so the shielded enclosure outside dimensions are relatively small compared to pyramidal foam for the same internal volume (see table 1). Ferrite tiles also have a durable surface and have stable performance with time.

Disadvantages are cost, the strong dependence of the reflectivity performance on both polarization and angle of incidence and possible non linear performance due to saturation at high field strengths.

Due to their relatively high cost ferrite tiles are mainly built up into 1 m or 2 m square blocks which are placed strategically in the chamber under pyramidal foam absorbers in the middle sections of the side walls, floor and ceiling, the main reflection paths between antennas (or between an antenna and EUT). They are also used on the end walls to improve absorption and to reduce image coupling.

This combination of ferrite tiles and pyramidal foam absorbers is more cost effective in performance terms than a fully ferrited room.

5.2.5 Ferrite grids

Ferrite grids are typically 10 cm by 10 cm by 2,5 cm thick. They provide absorption from 30 MHz to 1 000 MHz. The grid structure provides better power handling characteristics and avoids the installation problems associated with plain tiles. Their absorption characteristics are basically the same as for ferrite tiles (see figure 6).

5.2.6 Urethane/ferrite hybrids

Urethane/ferrite hybrid absorbers (as introduced in subclause 5.2.4) consist of pyramidal foam absorber bonded to a ferrite tile backing. They are designed in such a way that the ferrite tiles are active at the low frequencies, where the pyramidal foam absorbers are not very efficient, whilst the pyramidal absorbers take over at higher frequencies.

A disadvantage is the impedance mismatch between the ferrite base and the foam pyramids which results in performance degradation in some frequency ranges.

In a similar manner to the ferrite tile, the hybrid absorber is used in the middle sections of the side walls floor and ceilings - the main reflection paths between antennas (or between an antenna and EUT). They are also used on the end walls to improve absorption and to reduce image coupling.

5.2.7 Floor absorbers

Anechoic materials (except ferrite tiles and grids) cannot, in general, support loads. Normally, therefore, a false floor of RF transparent material is built above the anechoic materials, to enable access to the test antenna and turntable. It is, however, very difficult to obtain a floor that is truly RF transparent and the floor is often "visible". This tends to be revealed when the performance of the chamber is being verified and has been known to lead to constructional modifications.

Special types of floor absorbers can be used. These are constructed of normal pyramidal absorbers whose external profiled sections have been filled with a low loss rigid foam so as to form a solid block. This is usually capable of supporting the weight of a man, but with usage, degradation in performance occurs.

The most common solution is not to have a floor for access, but to arrange access to the antenna support, either with another access door (degrades chamber performance) or by making the antenna mount such that it can be easily moved to the turntable end to facilitate antenna changes etc.

5.2.8 Performance comparison

Table 1 and table 2 detail numerous relative parameters for the different absorber types discussed above. Table 1 gives the physical parameters relating to an anechoic chamber of internal testing dimensions of 8 m by 3 m by 3 m. Table 2 details the return loss (at 0° angle of incidence) for the various absorber types considered in table 1. The data in table 2 is shown graphically in figure 7.

Table 1: Typical physical parameters of an 8 m by 3 m by 3 m anechoic chamber for various absorber types

Features	Pyramidal 0,66 m	Pyramidal 1,778 m	Ferrite tiles	Ferrite grid	Hybrid
Inside dimensions	8 m by 3 m by 3 m	8 m by 3 m by 3 m	8 m by 3 m by 3 m	8 m by 3 m by 3 m	8 m by 3 m by 3 m
Outside dimensions (approx.)	9,32 m by 4,32 m by 4,32 m	11,56 m by 6,56 m by 6,56 m	8,02 m by 3,02 m by 3,02 m	8,05 m by 3,05 m by 3,05 m	9,35 m by 4,35 m by 4,35 m
Overall volume	174 m^3	497m^3	73 m^3	75 m^3	177 m^3
Flammable	yes	yes	no	no	yes
Risk of damage	high	high	low	low	high
Floor absorbers	moveable	fixed	fixed	fixed	fixed
Frequency range (MHz)	80 to >1 000	30 to >1 000	30 to >500	30 to >1 000	30 to >1 000

Table 2: Typically return loss at 0° incidence for various absorbers against frequency

Frequency	Pyramidal 0,66 m	Pyramidal 1,778 m	Ferrite tiles	Ferrite grid	Hybrid
30 MHz	7 dB	15 dB	17 dB	17 dB	16 dB
80 MHz	15 dB	25 dB	25 dB	20 dB	18 dB
120 MHz	19 dB	30 dB	26 dB	20 dB	20 dB
200 MHz	25 dB	35 dB	25 dB	37 dB	20 dB
300 MHz	30 dB	40 dB	23 dB	25 dB	20 dB
500 MHz	35 dB	45 dB	18 dB	23 dB	20 dB
800 MHz	40 dB	50 dB	14 dB	18 dB	25 dB
1 GHz	50 dB	50 dB	12 dB	15 dB	25 dB
3 GHz	50 dB	50 dB	6 dB	10 dB	30 dB
10 GHz	50 dB	50 dB	-	-	30 dB
18 GHz	50 dB	50 dB	-	-	35 dB

All of these types of absorber dissipate the energy incident on their surfaces in the form of heat. When in the presence of high value fields, the power absorbed in the foam variety can exceed its ability to dissipate the heat, and the resulting increase in temperature degrades its performance. This is not normally a problem with ferrite types.

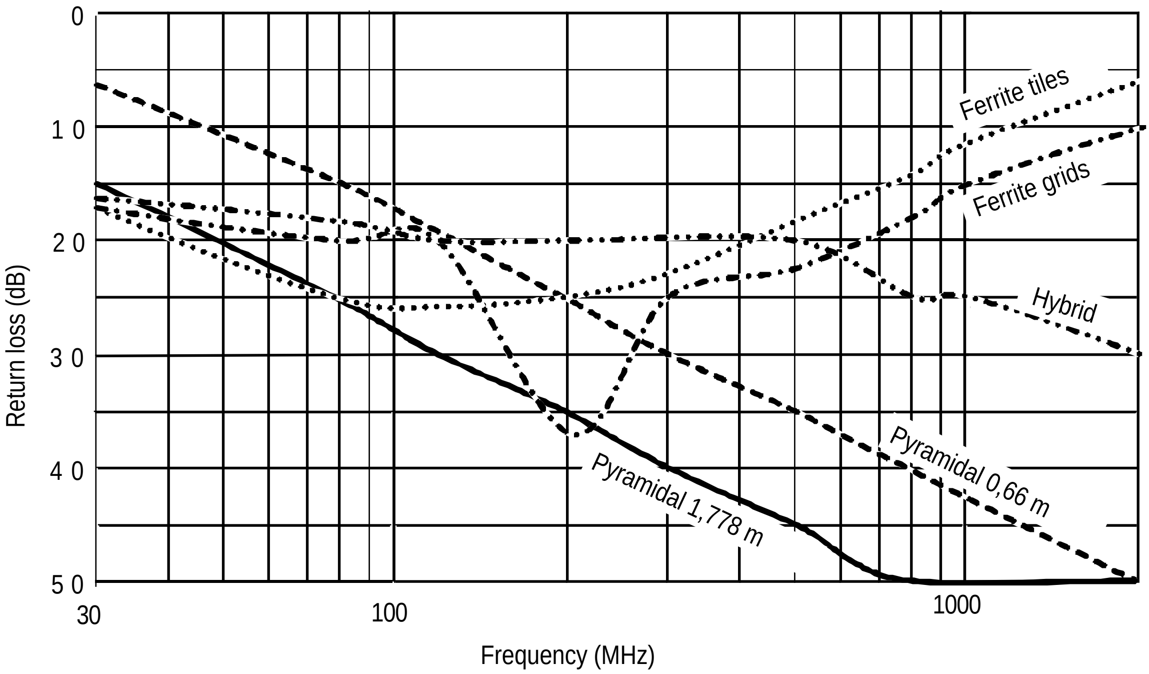


Figure 7: Return loss variation with frequency of the absorber performance given in table 2

5.2.9 Reflection in an anechoic chamber

As has been stated, the absorbing materials used and their layout play a critical role in the chamber's performance. A plan view of an anechoic chamber with its end and side walls covered in pyramidal foam absorbers is shown in figure 8. Mounted in the chamber are two dipoles (shown for illustration purposes only, although this is a common arrangement found in test methods and the verification procedure). Various single and double bounce reflection paths are also illustrated.

The single bounce reflection paths via the end walls are at normal incidence to the absorbers, and since the absorbers are at maximum efficiency at normal incidence the reflections are of a low amplitude. However the amplitude of the worst case reflections, the single bounce paths between the antennas via the side walls, are dependant on the angles of incidence, which themselves are dependant on the geometry (cross section and range length) of the chamber. The ceiling and floor provides other single bounce reflection paths.

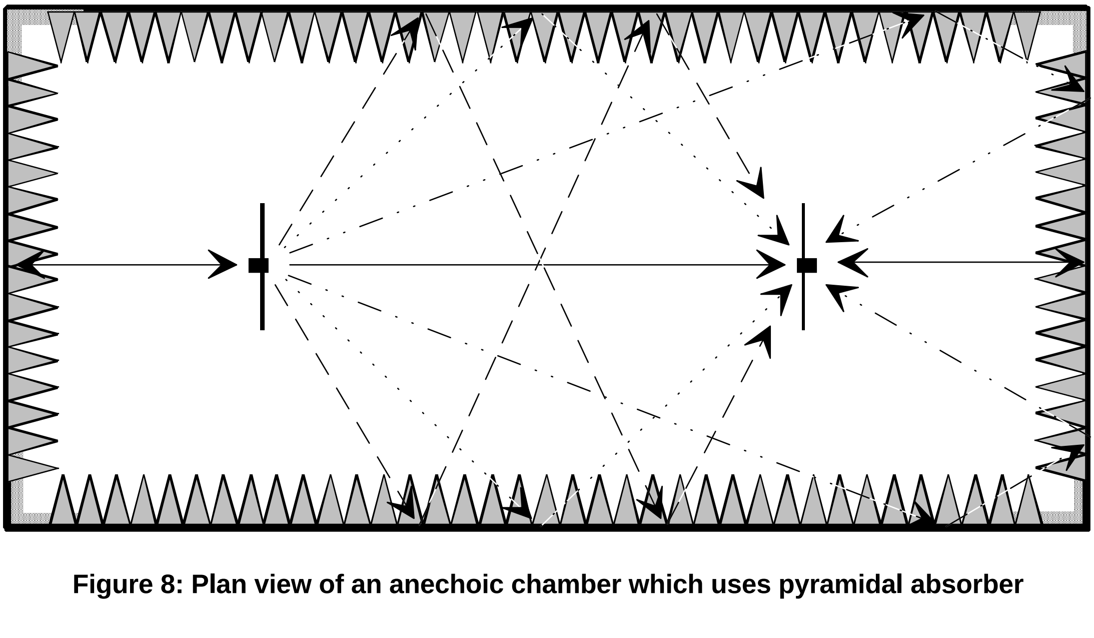


Figure 8: Plan view of an anechoic chamber which uses pyramidal absorber

The direct path between the antennas is the only wanted signal and all other signals, whether the result of reflections from the absorber or from extraneous sources (see subclause 5.3.1) interfere with the required field and result in measurement uncertainty. The situation is further complicated by the directional nature of the dipoles, reflections in the E-plane of the dipole being reduced in amplitude when compared to the case for the orthogonal polarization, as a result of the dipole's radiation pattern.

As an example of the magnitude of the problem, the following is calculated for illustrative purposes. A typical chamber of 5 m by 5 m by 7 m, employing 0,66 m pyramidal foam absorbers is used over a 3 m range length. The angles of incidence on the side walls, floor and ceiling of the main single bounce reflection paths are:

$$tan^{-1}(1,5 / 2,5) = 31,0°$$

Assuming a frequency of 80 MHz, the reflectivity at this angle of incidence is approximately 15 dB. If the polarization of the transmitting dipole is taken as horizontal, then its directivity in the horizontal plane reduces the magnitude of the side wall reflections by 1,9 dB which, in addition to the extra path length loss (relative to the direct ray) of 5,8 dB, leads to the amplitudes of the four main one-bounce reflections being -22,7, -22,7, -20,8 and -20,8 dB for the two side walls, floor and ceiling respectively (these levels being relative to the amplitude of the direct path).

NOTE: In a chamber of identical cross section but offering a 10 m range length, these four main interfering rays have greater amplitudes of approximately -13,4, -13,4, -12,0 and -12,0 dB as a result of increased reflectivity from the absorbing materials (grazing angle of incidence), less relative path loss (the path lengths are more nearly equal) and less benefit from the directivity of the dipole pattern.

Whilst the addition of these rays is rather more complex than just a straightforward addition (and for a full analysis one should also include multiple bounce reflections), their amplitudes serve to illustrate the potential problem of signal level uncertainty since, again for illustrative purposes only, a single -20 dB interfering signal can, at its maximum relative phasing, enhance or reduce the received signal strength by +0,83 or -0,92 dB respectively. Table 3 illustrates the uncertainty caused by a single unwanted interfering signal.

Table 3: Uncertainty in received signal level due to a single unwanted interfering signal

Ratio of unwanted to wanted signal level	Received level uncertainty	Ratio of unwanted to wanted signal level	Received level uncertainty
- 30,0 dB	+0,27 -0,28 dB	**- 9,0 dB**	+2,64 -3,81 dB
- 25,0 dB	+0,48 -0,50 dB	**- 8,0 dB**	+2,91 -4,41 dB
- 20,0 dB	+0,83 -0,92 dB	**- 7,0 dB**	+3,21 -5,14 dB
- 17,5 dB	+1,09 -1,24 dB	**- 6,0 dB**	+3,53 -6,04 dB
- 15,0 dB	+1,42 -1,70 dB	**- 5,0 dB**	+3,88 -7,18 dB
- 14,0 dB	+1,58 -1,93 dB	**- 4,0 dB**	+4,25 -8,66 dB
- 13,0 dB	+1,75 -2,20 dB	**- 3,0 dB**	+4,65 -10,69 dB
- 12,0 dB	+1,95 -2,51 dB	**- 2,0 dB**	+5,08 -13,74 dB
- 11,0 dB	+2,16 -2,88 dB	**- 1,0 dB**	+5,53 -19,27 dB
- 10,0 dB	+2,39 -3,30 dB	**0,0 dB**	+6,04 -∞ dB

For optimized chamber performance therefore, the middle sections of the ceiling, floor and side walls should be carefully constructed to provide the highest values of absorption in the chamber, especially for range lengths greater than 3 m. From a measurement viewpoint the amount of reflection from the walls has a direct effect on the "quality" of the measurement.

Experience has shown that in chambers which have 0,66 m pyramidal absorbers the overall performance has three distinct stages:

- below about 150 MHz or so the amplitude of reflections from the walls, floor and ceiling can be observed to degrade the operation of the facility. The shielded enclosure may act as a large cavity resonator, although all possible modes may not be excited as they are dependant on the configurations of the test equipment and EUT;

- from about 150 MHz up to a few hundred MHz most of the components (e.g. absorber dimensions) return to full specification and the chamber tends to "behave" quite well;

- at very high frequencies, arbitrarily hundreds of MHz to well above 1 000 MHz resonances can be set up by the physical dimensions of the absorber material which can negate the fact that the absorber materials themselves have good performance characteristics at these frequencies.

In this ETR, the uncertainty contributions due to reflectivity of the absorbers are estimated in ETR 273-1-1 [8] annex A and given representative symbols as follows:

u_{j01} is used for the contribution associated with the reflectivity of the absorbing material between the EUT and the test antenna in test methods;

u_{j02} is used for the contribution associated with the reflectivity of the absorbing material between the substitution or measuring antenna and the test antenna in test methods;

u_{j03} is used for the contribution associated with the reflectivity of the absorbing material between the transmitting antenna and the receiving antenna in verification procedures.

5.2.10 Mutual coupling due to imaging in the absorbing material

Mutual coupling is the mechanism which produces changes in the electrical behaviour of an antenna (or EUT) when placed close to a conducting surface, another antenna, etc. The changes can include, amongst others, de-tuning, gain variation and changes to the radiation pattern. Whilst the absorbing material helps to reduce these effects, it does not remove them completely. To avoid the major effects of any such performance changes, it is a stipulation in all tests, that no part of any antenna, or EUT, should at any time, approach to within less than 1 m of any absorbing material. Where this condition cannot be satisfied, testing should not be carried out.

The magnitude of the effects on the electrical characteristics due to the degree of imaging in the absorber/shield of the chamber are estimated in ETR 273-1-1 [8] annex A and the uncertainty contributions due to the mutual coupling effects to the absorber materials are given representative symbols as follows:

u_{j04} is used for the uncertainty contribution associated with the EUT and its images in the absorbing material in test methods;

u_{j05} is used for the uncertainty contribution associated with the de-tuning effect of the absorbing material on the EUT in test methods;

u_{j06} is used for the uncertainty contribution associated with the substitution, measuring or test antenna and its images in the absorbing material in test methods;

u_{j07} is used for the uncertainty contribution associated with the transmitting or receiving antenna and its images in the absorbing material in verification procedures.

5.3 Other effects

5.3.1 Extraneous reflections

Within the chamber, reflecting objects such as internal lighting, cameras and safety circuits (which are normally used in chambers where high power fields are generated) should be avoided (or their effects minimized) as they will have a direct effect on the quality of the measurement at that site. Similarly, the materials from which the antenna mount and turntable are constructed should be of low relative dielectric constant.

5.3.2 Mutual coupling between antennas (or antenna and EUT)

Mutual coupling, as stated in subclause 5.2.10, is the mechanism which produces changes in the electrical behaviour of an EUT (or antenna) when placed close to a conducting surface, another antenna, etc. The changes can include detuning, gain variation and distortion of the radiation pattern.

To illustrate the mutual coupling effects between antennas it is useful to start by considering the interaction between two closely spaced resonant dipoles in **free space**. Some texts [2] show that in this condition, noticeable changes to the dipole's input impedance result for dipole to dipole spacing of up to 10 wavelengths (assuming side by side orientation).

In a transmit/receive system between two resonant dipoles the input impedance of the driven dipole (Z_{in1}) can be calculated as a combination of its own self impedance (Z_{11}), the self impedance of the other dipole (Z_{22}) and a contribution from the mutual interaction between them which comprises both resistive (R_{12}) and reactive (X_{12}) components. The relationship between them can be shown to be:

$$Z_{in1} = Z_{11} - \frac{(R_{12} + jX_{12})^2}{Z_{22}}$$

The variations with spacing of the mutual resistance and reactance for two half wavelength dipoles are shown in figure 9.

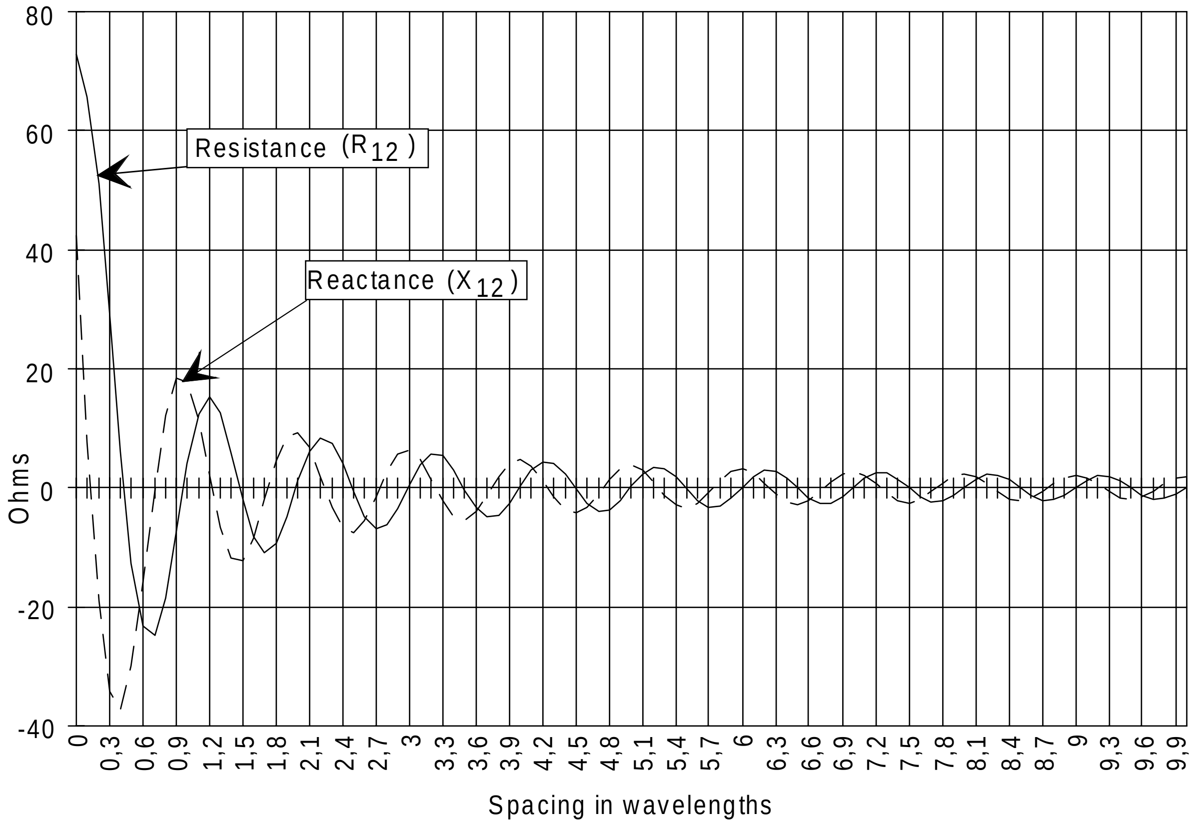
EXAMPLE: if the spacing is 3 m and the frequency is 30 MHz, from figure 9, R_{12} = 29,11 Ω and X_{12} = - 34,36 Ω. As a result, Z_{in1} = 88,32 + j 60,98 Ω whereas with no coupling it would have been 73 + j 42,5 Ω.

EXAMPLE: the input impedance of the transmitting antenna for two half wavelength dipoles spaced half a wavelength apart, becomes 70 + j 30,5 Ω as a result of the mutual coupling.

Along with the change in input impedances arising from mutual coupling, there will be a signal strength loss due to the associated mismatch to the line. However, it is not only the dipole impedance that changes as a result of its proximity to another. The radiation pattern and gain (or antenna factor) will also change. Indeed, the gain change has been shown [10] to have an unexpected relationship with the radiation resistance - namely that their product remains constant no matter how much either quantity may vary. Specifically:

$$Gain = 120 / Resistance$$

As a result, for the first example above (30 MHz dipoles spaced 3 m apart) a gain loss of 0,83 dB occurs whilst for the second example of two dipoles half a wavelength apart an increase of 0,19 dB results. Simply increasing the spacing to minimize mutual coupling, requires a receiver with sufficient sensitivity to cope with the increased path loss.



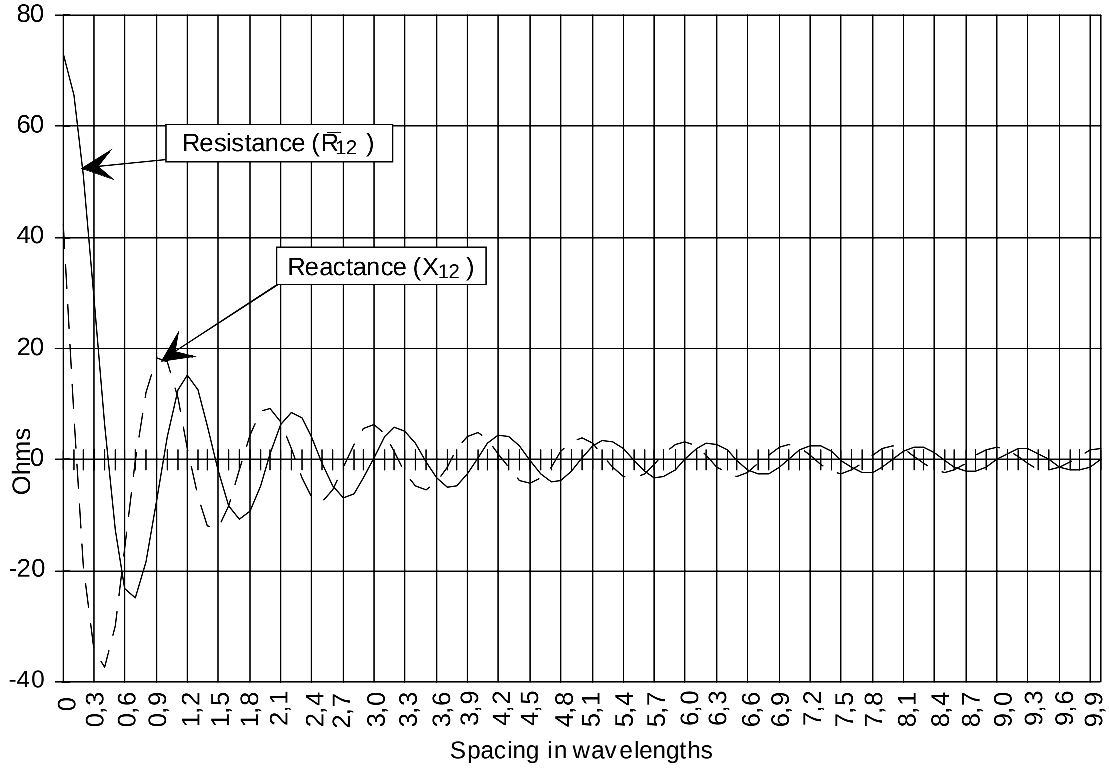


Figure 9: The mutual resistance and reactance of 2 side-by-side dipoles, each $\lambda/2$

The magnitude of the effects on the electrical characteristics of the EUT (or antenna) due to the mutual coupling between them are estimated in ETR 273-1-1 [8] annex A and the uncertainty contributions which result are given representative symbols as follows:

u_{j08} is used for the uncertainty contribution associated with the amplitude effect of the test antenna on the EUT in test methods;

u_{j09} is used for the uncertainty contribution associated with the de-tuning effect of the test antenna on the EUT in test methods;

u_{j10} is used for the uncertainty contribution associated with the mutual coupling between transmitting antenna and receiving antenna in verification procedures;

u_{j11} is used for the uncertainty contribution associated with the mutual coupling between substitution or measuring antenna and test antenna in test methods.

5.3.3 Turntable and antenna mounting fixtures

As the turntable and mounting fixtures are in close proximity to the EUT/antenna they can significantly change its performance. The antenna mount likewise for the test antenna. The antenna mount, turntable and mounting fixtures should, therefore, be constructed from non-conducting, low relative dielectric constant plastics or wood to reduce reflections and interactions. It is recommended that materials with dielectric constants of less than 1,5 be used for all supporting structures.

Structurally, the antenna mount should be sufficiently strong to prevent twisting under load, since the antenna pattern might move "off axis" with the result that the signal level may not be maximized (see figure 10). In a substitution type measurement, however, provided the antenna is not repositioned between the two stages of the test, any such error in alignment should cancel itself out.

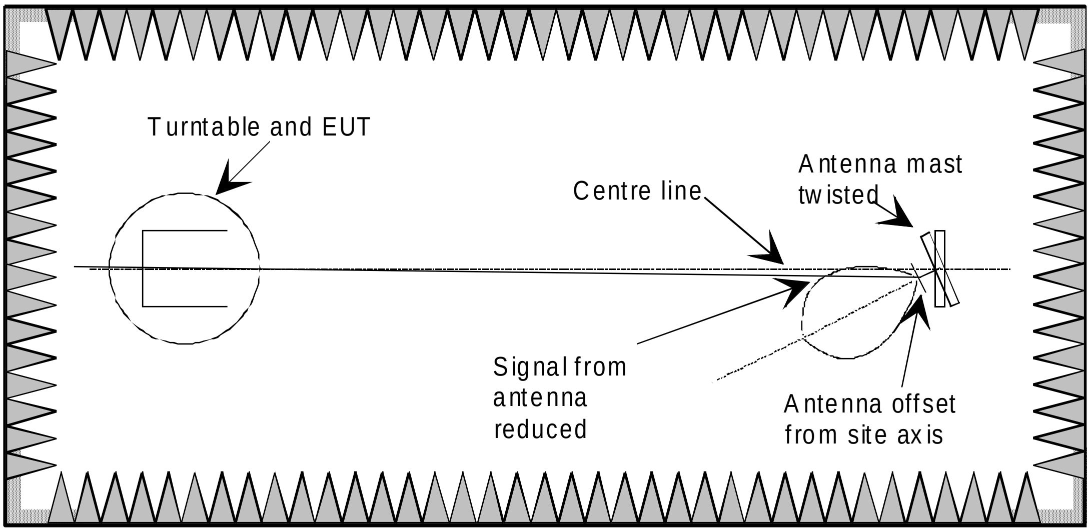


Figure 10: Signal reduction due to a twisted mast (plan view)

The stability of the turntable is also important since an unstable, or non uniform turntable will change the measurement distance as it is rotated.

The controller for the turntable should also be carefully considered to avoid measurement errors. For example, rapid changes in speed of rotation can lead to missing peak values. Settling times are important for measuring equipment in some tests e.g. SINAD measurement. The controller should, therefore, be designed with fixed, acceptable speeds to avoid problems of this sort.

5.3.4 Antenna cabling

There are radiating mechanisms by which RF cables can introduce uncertainties into radiated measurements:

- leakage;
- acting as a parasitic element to the antenna;
- introducing common mode current to the balun of the antenna.

Leakage allows electromagnetic coupling into the cables. Because the electromagnetic wave contains both electric and magnetic fields, mixed coupling can occur and the voltage induced is very dependant on the orientation, with respect to the cable, of the fields. This coupling can have different effects depending on the length of the cable and where it is in the system. Cables are usually the longest part of the test equipment configuration and, as such, leakage can make them act as efficient receiving or transmitting antennas thereby contributing significantly to the uncertainty of a measurement.

The parasitic effect of the cable can potentially be the most significant of the three effects and can cause major changes to the antenna's radiation pattern, gain and input impedance. The common mode current problem has similar effects on the antenna's performance.

All three effects can be largely eliminated by routeing and loading the cables with ferrite beads as detailed in the test methods. A cable for which no precautions have been taken to prevent these effects can cause different results to be obtained simply by being repositioned.

u_{j19} is used for the uncertainty contribution associated with cable factor (the combined uncertainty which results from interaction between any antenna and its cable).

5.3.5 Positioning of the EUT and antennas

The phase centre of an EUT (or antenna) is the point within the EUT (or antenna) from which it radiates. If the EUT (or antenna) was rotated about this point, the phase of the received/transmitted signal would not change. For some test procedures, especially those which require an accurate knowledge of the measurement distance, it is vital to be able to identify the phase centre.

Where an EUT is being tested the uncertainty in the position of the phase centre of the source within the EUT volume can lead to signal level uncertainties since all calculations deriving emission or sensitivity levels will be based on the precise measurement distance.

u_{j20} is used for the uncertainty contribution associated with not knowing the exact position of the phase centre within the EUT volume.

The positioning, on the turntable, of the phase centre of the EUT's radiating source, can lead to uncertainties if it is offset from the table's axis of rotation. Any offset will cause the source to describe a circle about the axis as the EUT is rotated. Variations in path lengths (both direct and reflected) are thereby introduced leading directly to changes in the received/transmitted field strength.

u_{j21} is used for the uncertainty contribution associated with the positioning of the EUT's phase centre over the axis of rotation of the turntable.

The phase centre of an antenna (or any other radiating structure) is the point from which it can be considered to radiate. If the antenna (or radiating structure) was rotated about this point, the phase of the received/transmitted signal would not change. The phase centre of both a dipole and biconic antenna is in the centre of its two arms, for an Log Periodic Dipole Antenna (LPDA) it should be assumed to be halfway along its longitudinal axis and for a waveguide horn it is the centre of its open mouth.

u_{j22} is used for the uncertainty contribution associated with the positioning of the phase centre of the measuring, substitution, receiving, transmitting or test antenna.

Certain antennas, most notably the LPDA, possess a phase centre which is difficult to pinpoint at any particular frequency. Further, for this type of antenna the phase centre moves along the array with changing frequency resulting in a measurement distance uncertainty (e.g. an LPDA with a 0,3 m length contributes a standard uncertainty level due to range length uncertainty of u_j = 1,0 dB). To use such an antenna for site verification, for example, could introduce large uncertainties.

u_{j23} is used for the uncertainty contribution associated with not knowing the exact position of the phase centre for LPDAs.

5.3.6 Equipment cabling

EUT cable layout can contribute significantly to the uncertainty of a measurement. Large variations can occur when measuring spurious emissions for example as a result of the positions of the supply and control cables.

These cables can act as parasitic elements and can receive, transmit or reflect radiated fields. The effects vary with cable type, the configuration and use, but they may strongly influence the outcome of a measurement. A number of schemes can be used to reduce these problems, amongst which are a total replacement by fibre optic cables and twisting wires together and loading them with ferrite beads.

u_{j55} is used for the uncertainty contribution which results from interaction between the EUT and the power leads.

6 Verification procedure for an anechoic chamber

6.1 Introduction

The verification procedure is a process carried out in anechoic chambers, anechoic chambers with ground planes, open area test sites and striplines to prove their suitability as free field test sites.

Anechoic chambers and open area test sites

For both types of anechoic chamber (i.e. both with and without a ground plane) and open area test sites the verification procedure involves the transmission of a known signal level from one calibrated antenna (usually a dipole) and the measurement of the received signal level in a second calibrated antenna (also usually a dipole).

By comparison of the transmitted and received signal levels, an "insertion loss" can be deduced. After inclusion of any correction factors for the measurement, the figure of loss which results from the verification procedure, is known as "site attenuation".

Site attenuation is defined [11] as "the ratio of the power input of a matched, balanced, lossless, tuned dipole radiator to that at the output of a similarly matched, balanced, lossless, tuned dipole receiving antenna for specified polarization, separation and heights above a flat reflecting surface. It is a measure of the transmission path loss between two antennas".

As the definition states ".... above a flat reflecting surface", it is usual for the verification procedure to involve one antenna (the transmitting antenna) remaining fixed in height whilst a second antenna (the receiving antenna) is scanned through a specified height range looking for a peak in the received signal level.

The parameter of site attenuation originated for open area test sites, hence the reference to a reflective ground plane in the definition. The term is, however, also used in association with anechoic chambers. The measurement of site attenuation in such an anechoic chamber provides an equally good measure of the facility's quality as it does for an open area test site. Without a "flat reflecting surface", an anechoic chamber has no ground reflection and hence a vertical height scan is unnecessary.

The determination of site attenuation involves two different measurements of received signal level. The first is with all the items of test equipment connected directly together via an adapter, whilst the second involves replacing the adapter with a pair of antennas. The difference in received levels (after allowance for any relevant correction factors which may be appropriate), for the same signal generator output level, is the site attenuation.

The verification procedure for an anechoic chamber is based on EN 50147-2 [7], which itself is based on that given in CISPR 16-1 [6] and subclauses 15.4 to 16.6.3 inclusive. Both procedures call for the determination of Normalized Site Attenuation (NSA) which is equivalent to site attenuation after subtraction of the antenna factors and any mutual coupling effects. It should be noted that both publications EN 50147-2 [7] and CISPR 16-1 [6] only detail verification procedures in the 30 MHz to 1 000 MHz frequency band.

It is particularly for the verification of open area test sites that NSA has historically found use. However, the same approach has also been adopted in the verification procedure which follows for the anechoic chamber.

6.2 Normalized site attenuation

NSA is determined from the value of site attenuation by subtraction of the antenna factors and mutual coupling effects. The subtraction of the antenna factors makes NSA independent of antenna type.

NOTE: The uncertainty of the resulting value for NSA depends directly on the uncertainty with which the antenna factors are known.

Symbolically,

$$NSA = V_{direct} - V_{site} - AF_T - AF_R - AF_{TOT}$$

where:
- V_{direct} = received voltage for cables connected via the "in-line" adapter;
- V_{site} = received voltage for cables connected to the antennas;
- AF_T = antenna factor of the transmit antenna;
- AF_R = antenna factor of the receive antenna;
- AF_{TOT} = mutual coupling correction factor.

The verification procedure compares the measured NSA (after relevant corrections) against the theoretical figure calculated for an ideal anechoic chamber. The difference between the two values at any specific frequency is a measure of the quality of the chamber at that frequency.

The relevant theory for deriving the NSA of an ideal anechoic chamber is given below.

6.2.1 NSA for the ideal anechoic chamber

In an ideal anechoic chamber where there are:

- no unwanted reflections (ground reflected or others);
- no interaction between transmit and receive dipoles;
- no coupling of the dipoles to the absorbing material;
- perfectly aligned, loss-less, matched tuned dipoles are used;

the coupling between the dipoles (assumed to be half wavelength) is given by the Friis transmission equation (as derived in clause 7 of ETR 273-1-1 [8]):

$$P_{rec} = \left(\frac{\lambda}{4\pi d}\right)^2 1{,}643^2 \left(\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right)^2 \left(\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right)^2 P_t$$

where: P_t = power transmitted (W);
P_{rec} = power received (W);
λ = wavelength (m);
d = distance between dipoles (m);

and θ is a spherical co-ordinate, as shown in figure 11.

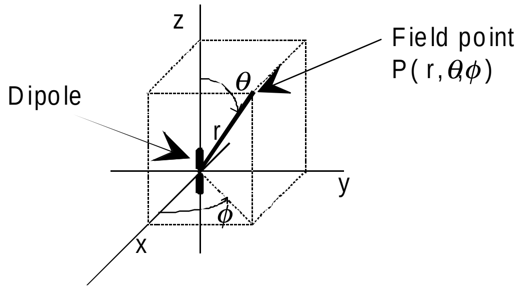


Figure 11: Spherical co-ordinates

For this ideal site, the site attenuation (the inverse of the Friis transmission equation) is given by:

$$\frac{P_t}{P_{rec}} = \left(\frac{4\pi d}{\lambda}\right)^2 \frac{1}{1{,}643^2} \left(\frac{\sin\theta}{\cos\left(\frac{\pi}{2}\cos\theta\right)}\right)^2 \left(\frac{\sin\theta}{\cos\left(\frac{\pi}{2}\cos\theta\right)}\right)^2$$

More usually, this formula is given in logarithmic terms as follows:

$$Site\ Attenuation = 17{,}67 + 20\log\left(\frac{d}{\lambda}\right) + 20\log\left(\frac{\sin\theta}{\cos\left(\frac{\pi}{2}\cos\theta\right)}\right) + 20\log\left(\frac{\sin\theta}{\cos\left(\frac{\pi}{2}\cos\theta\right)}\right)\ \text{dB}$$

For an anechoic chamber, since both transmit and receive antennas are assumed to be at the same height, $\theta = \pi / 2$ and the formula reduces to:

$$Site\ Attenuation = 17{,}67 + 20\log(d/\lambda)\ \text{dB}$$

NOTE 1: In an actual measurement, the value of site attenuation is likely to be greater than given by this formula due to mismatch and resistive losses, mutual coupling effects, etc.

An alternative formulation for site attenuation, based on field strengths and antenna factors has been derived in [3]. The resulting formulae are for use with ground reflection sites but they are easily adapted for the fully anechoic chamber.

The general formula given for site attenuation, *A*, is:

$$A = \frac{279{,}1\ AF_T\ AF_R}{f_m E_{D(H\ or\ V)}^{\max}}$$

where AF_T = antenna factor of the transmitting antenna (m^{-1}),

AF_R = antenna factor of the receiving antenna (m^{-1}),

f_m = frequency (MHz) and

$_{D(H\ or\ V)}^{max}$ = calculated maximum electric field strength (µV/m) in the receiving antenna height scan from a half wavelength dipole with 1 pW of radiated power.

$E_{D(H\ or\ V)}^{max}$ = takes the form E_{DH}^{max} for horizontal polarization and E_{DV}^{max} for vertical polarization.

NOTE 2: The stipulations of a half wavelength dipole and 1 pW of radiated power in $E_{D(H\ or\ V)}^{max}$ do not limit the use of the site attenuation equation to those conditions. The definition of $E_{D(H\ or\ V)}^{max}$ in the text of [3] is for convenience only and the stipulated conditions cancel out in the final formulae for site attenuation and NSA, both of which apply generally.

For the anechoic chamber, $E_{D(H\ or\ V)}^{max}$ (a term whose amplitude is generally peaked on a ground reflection range by height scanning on a mast) is simply replaced by $E_{D(H\ or\ V)}$ since no maximization is involved. Also both polarizations behave similarly and $E_{D(H\ or\ V)}$ can be shown to be:

$$E_{DH} = E_{DV} = 7{,}01/d$$

In decibel terms, the site attenuation formula becomes:

$$A = 48{,}92 + 20 \log (AF_T) + 20 \log (AF_R) - 20 \log f_m - 20 \log (7{,}01/d)\ \text{dB}$$

The formula for NSA then follows as:

$$NSA = A - 20 \log (AF_T) - 20 \log (AF_R)\ \text{dB}$$

$$i.e. \quad NSA = 48{,}92 - 20 \log f_m - 20 \log (7{,}01/d)\ \text{dB}$$

6.2.2 Mutual coupling

Mutual coupling may exist between the antennas during the verification procedure. This will serve to modify the results since it can change antenna input impedance/voltage standing wave ratio and gain/antenna factors of both dipoles. Figure 12 shows schematically mutual coupling as it occurs between dipoles in a reflection-free environment.

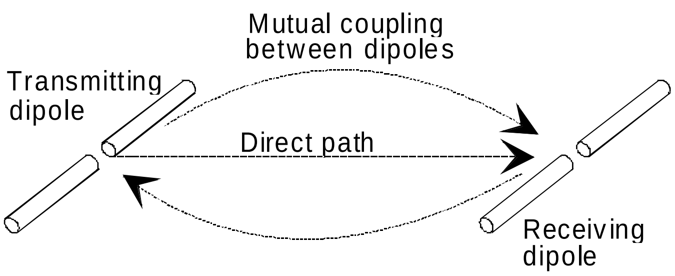


Figure 12: Direct path and mutual coupling

For accurate determination of NSA these additional effects needs to be taken into consideration and correction factors should be applied to the measured results to compensate.

In the verification procedure that follows, tables of correction factors are provided for mutual coupling between dipoles, where appropriate, for 3 m and 10 m range lengths.

6.3 Overview of the verification procedure

The first steps in the verification procedure are the gathering of all the appropriate test equipment (subclause 6.3.1) and preparation of the site (subclause 6.3.2).

The test equipment should then be configured (subclause 6.3.3), and the verification procedure carried out (subclause 6.4).

On completion of the verification procedure, the results need to be processed (subclause 6.5) so that at each test frequency a value for the deviation of the chamber performance from the ideal can be calculated and plotted (figure 23) and the measurement uncertainties calculated (subclauses 6.6 and 6.7).

The verification procedure (subclause 6.4) recommends an antenna scheme in the 30 MHz to 1 000 MHz frequency band which uses tuned, half wavelength dipoles for all frequencies in the range 80 to1 000 MHz and shortened dipoles (subclause 6.3.3) below 80 MHz.

NOTE: For cases in which this is not suitable, an alternative scheme using dipoles and bicones (possibly also LPDAs) is suggested in subclause 6.3.2. It should be noted that measurement uncertainty is likely to be degraded if the recommended dipole scheme is not used.

For the 1 GHz to 12,75 GHz band, broadband antennas (LPDAs) are recommended.

Throughout the whole band of 30 MHz to 12,75 GHz, the procedure involves discrete frequencies only. For the frequency range 30 MHz to 1 000 MHz, the frequencies have been taken from CISPR 16-1 [6] annex G.

Figure 13 shows a typical verification testing arrangement of antennas (for the lower band) and test equipment.

6.3.1 Apparatus required

- attenuator pads, 10 dB;
- connecting cables;
- ferrite beads;
- receiving device (measuring receiver or spectrum analyser);
- signal generator;
- transmit antenna;
- receive antenna.

For frequencies from 30 MHz to 1 000 MHz:

- transmit antenna (half wavelength dipole as detailed in ANSI C63.5 [1] recommended);
- receive antenna (half wavelength dipole as detailed in ANSI C63.5 [1] recommended).

NOTE 1: Alternatively dipoles plus bicones or dipoles plus bicones and LPDAs may be used.

NOTE 2: The reference dipole antennas, incorporating matching/transforming baluns, for the procedure are available in the following bands: 20 MHz - 65 MHz, 65 MHz - 180 MHz, 180 MHz - 400 MHz, 400 MHz - 1 000 MHz. Constructional details are contained in ANSI C63.5 [1]. In the recommended antenna scheme for verification in this band, a shortened dipole is used at all frequencies from 30 MHz to 70 MHz inclusive.

For frequencies above 1 000 MHz:

- Transmit antenna (LPDA 1 GHz to 12,75 GHz);
- Receive antenna (LPDA 1 GHz to 12,75 GHz).

The type and se d in the results sheet relevant to the frequenc 8 for the 1 MHz - 12,75 GHz band.

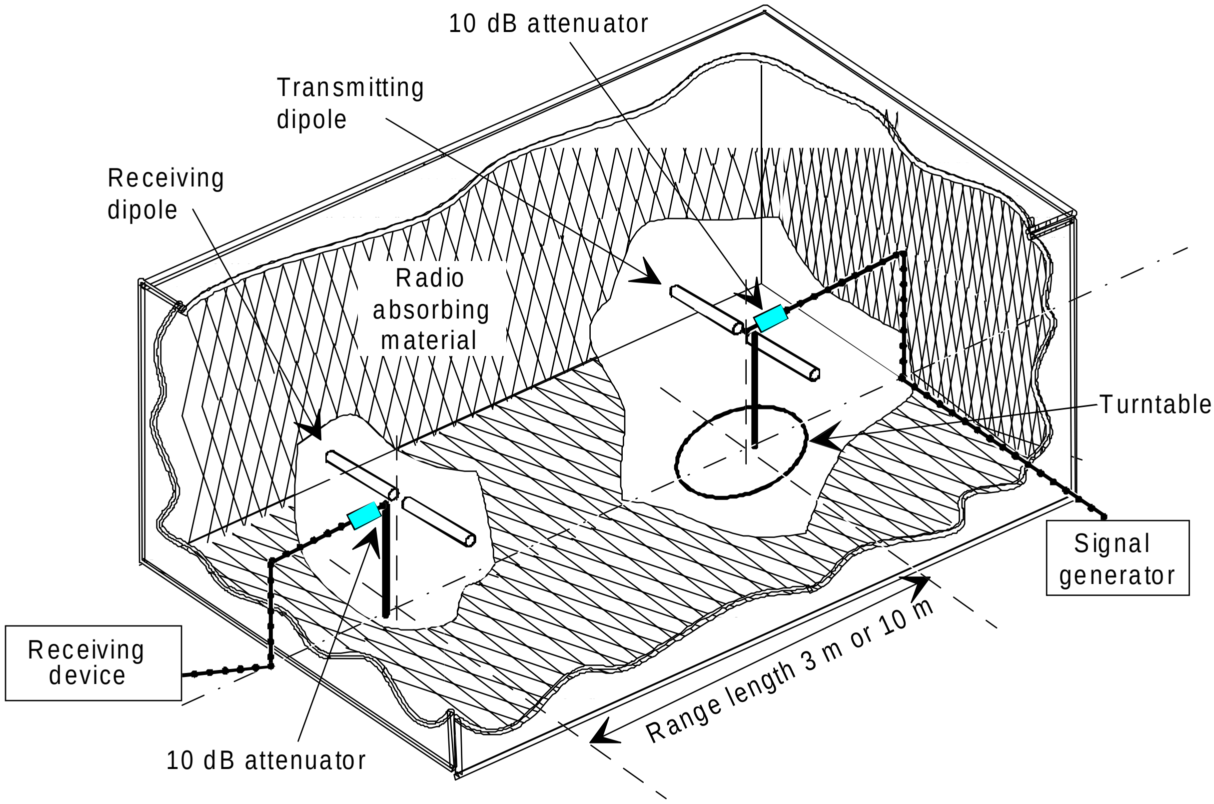


Figure 13: Site layout for the verification procedure using horizontally polarized dipoles in an anechoic chamber

6.3.2 Site preparation

Prior to the start of the verification procedure, system checks should be made on the test equipment to be used. All items of test equipment where appropriate, should be connected to power supplies, switched on and allowed adequate time to stabilize, as recommended by the manufacturers. Where a stabilization period is not given by the manufacturer, 30 minutes should be allowed.

The cables for both ends of the chamber should be routed behind and away from the antennas, parallel to the side walls and floor of the chamber, towards the back walls for a minimum of 2 m (unless the back wall is reached). They should then be allowed to drop vertically towards the floor, preferably behind the anechoic panels, and routed out through the screen (normally via a breakout panel) to the test equipment.

These cables should be dressed with ferrite beads, spaced 0,15 m apart for their entire lengths within the screen of the chamber. The cables, their routeing and dressing should be the same as for the normal operation of the chamber.

Calibration data for all items of test equipment should be available and valid. For all non-ANSI dipoles, the data should include VSWR and antenna factor (or gain) against frequency. The calibration data for all cables and attenuators should include insertion loss and VSWR throughout the entire frequency range of the tests. Where any correction factors/tables are required, these should be immediately available.

6.3.3 Measurement configuration

For the frequency band 30 MHz to 1 000 MHz, both antennas should be tuned half-wavelength dipoles (constructed as detailed in ANSI C63.5 [1]) aligned for the same polarization.

NOTE 1: Due to size constraints a shortened dipole is used over part of this frequency band. For uniformity of verification procedure across open area test sites and both types of anechoic chamber, a shortened dipole is used from 30 MHz - 70 MHz inclusive. At all these frequencies the 80 MHz arm length (0,889 m) is used attached to the 20 MHz - 65 MHz balun for all test frequencies in the 30 MHz - 60 MHz band and to the 65 MHz - 180 MHz balun for 70 MHz. Tuned half wavelength dipoles, attached to their matching baluns are used for all frequencies in the band 80 MHz - 1 000 MHz inclusive. Table 4 details dipole arm lengths (as measured from the centre of the balun block) and balun type against frequency.

Table 4: Dipole arm length and balun type against frequency

Frequency (MHz)	Dipole arm length (m)	Balun type	Frequency (MHz)	Dipole arm length (m)	Balun type
30	0,889	20 MHz to 65 MHz	**160**	0,440	65 MHz to 180 MHz
35	0,889		**180**	0,391	
40	0,889		**200**	0,352	180 MHz to 400 MHz
45	0,889		**250**	0,283	
50	0,889		**300**	0,235	
60	0,889		**400**	0,175	
70	0,889	65 MHz to 180 MHz	**500**	0,143	400 MHz to 1 000 MHz
80	0,889		**600**	0,117	
90	0,791		**700**	0,102	
100	0,714		**800**	0,089	
120	0,593		**900**	0,079	
140	0,508		**1 000**	0,076	

For the 30 MHz - 1 000 MHz band, the restriction that no part of an antenna should come within 1 metre of any part of the absorbing panels puts a limit on the number of combinations of transmitting antenna positions and polarizations for this procedure. For each polarization, five positions within the chamber are verified. These are shown in figures 14 and 15. Optionally, four further positions, shown in outline in these figures and figure 19 (where the H and V suffices refer to horizontal and vertical polarizations respectively) can be tested for each polarization if required. Correction factors (where appropriate) and NSA data are supplied for all positions, including the optional ones.

The same antenna positions/polarization scheme is used in the 1 GHz - 12,75 GHz band for which both antennas should be LPDAs, aligned for the same polarization.

NOTE 2: When the transmitting LPDA is used at positions other than on the central axis of the chamber, the transmitting and receiving antennas should be aligned for maximum signal i.e. they should point directly towards each other.

For both bands, the measured NSA is determined for all positions/polarizations.

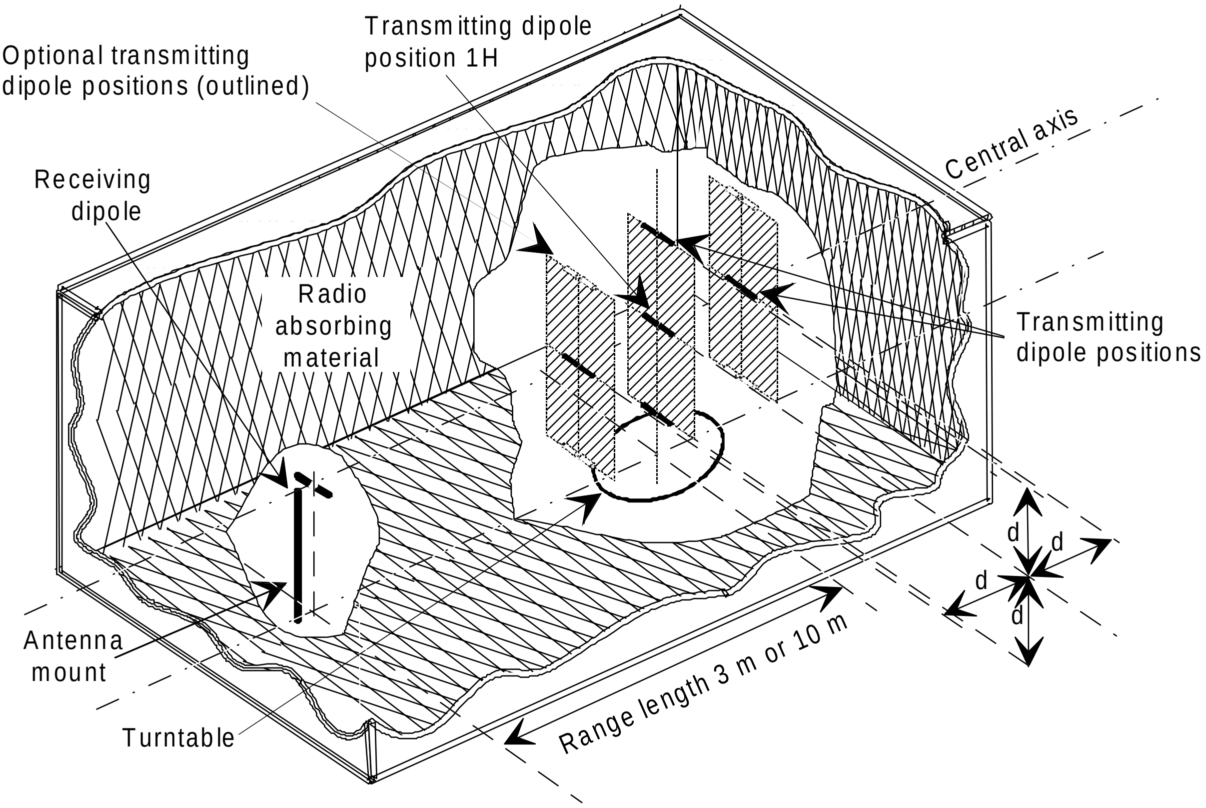


Figure 14: Antenna arrangements for horizontal polarization

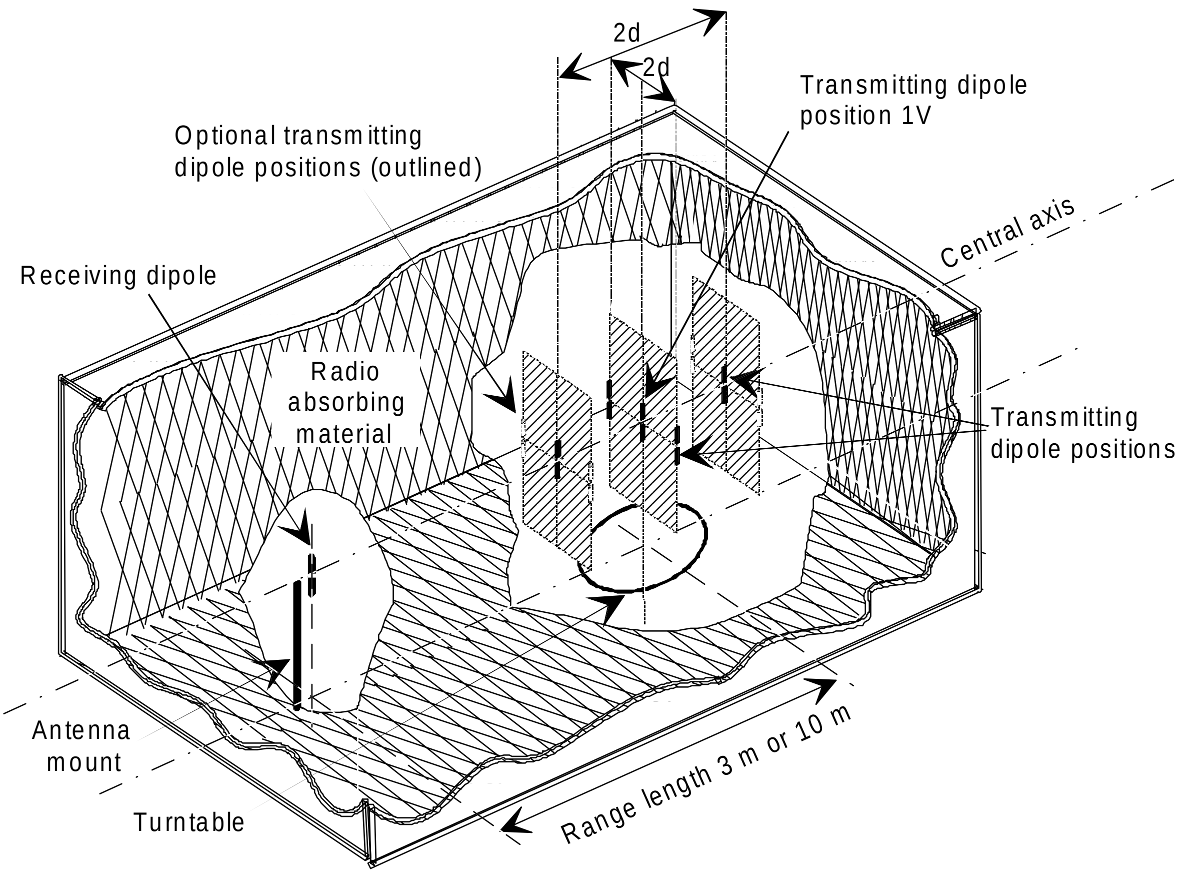


Figure 15: Antenna arrangements for vertical polarization

6.3.4 What to record

During the course of the procedure the chamber ambient temperature and relative humidity should be recorded.

Also during the course of the procedure, the output level of the signal generator, the received level, the tuned frequency and polarization of the antennas should be recorded along with ALL equipment used signal generator, receiver, cables, connectors, etc. An example of the results sheet is shown in table 5. A set of 10 results sheets (optionally 18), one corresponding to each position/polarization of the transmitting antenna, should be completed for each frequency band.

NOTE: The results sheet for 1,0 to 12,75 GHz verification (see table 8) is identical to table 5 except for the omission of the column for mutual coupling correction factor AF_{TOT}. Where LPDAs are used, no corrections for mutual coupling are necessary.

Table 5: Example of an anechoic chamber verification results sheet

anechoic chamber verification procedure results sheet								**30 to 1 000 MHz**
Range length: 3m **Ambient temperature: 20°C**			**Polarization: Horizontal** **Position No.: 1H**			**Date:** **Relative humidity: 60 %**		
Freq. (MHz)	**Direct** V_{direct} **(dBμV)**	**Site** V_{site} **(dBμV)**	**Transmit Antenna factor** AF_T **(dB)**	**Receive Antenna factor** AF_R **(dB)**	**Mutual coupling correction** AF_{TOT} **(dB)**	**Overall value (dB)**	**Ideal value (dB)**	**Difference (dB)**
Transmit antenna: Dipole S/No. D 001 Transmit antenna cable: Ref. No. C 128 Signal generator: Ref. No. SG 001 Attenuator: S/No. AT 01 Ferrite type: Worry beads					Receive antenna: Dipole S/No. D 002 Receive antenna cable: Ref. No. C 129 Receiving device: Ref. No. SA 001 Attenuator: S/No. AT 02 Ferrite manufacturer: Rusty co. Ltd.			

6.4 Verification procedure

Introduction

Two different procedures, one for each frequency band, are involved in verifying the performance of an anechoic chamber which is used for the band 30 MHz to 12,75 GHz. The first procedure covers 30 MHz to 1 000 MHz and the second covers 1 GHz to 12,75 GHz.

6.4.1 Procedure 1: 30 MHz to 1 000 MHz

Direct attenuation

1) The two antenna cables should be connected together, via attenuator pads and an "in-line" adapter as shown in figure 16. Alternatively, if this is not practical, a calibrated cable may be used instead of the adapter.

NOTE 1: The use of a cable will increase the overall measurement uncertainty.

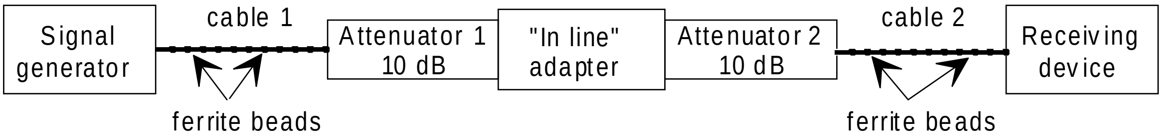


Figure 16: Initial equipment arrangement for the verification tests

2) The output of the signal generator should be adjusted to an appropriate level. The minimum acceptable level for any frequency in the band of interest may be calculated from:

- 20 dB above the maximum expected radiated path loss (20 log ((4π range length)/λ)), plus the ambient noise floor, the value of the attenuator pads and the cable losses, minus the antenna gains.

NOTE 2: For practical purposes it is advisable to set a single output level for all frequencies in the band, since this avoids level changes during the verification. Therefore this calculation should be evaluated at 30 MHz, the worst frequency, since the reduced sensitivity of the shortened dipoles at this frequency requires an enhanced signal level 53 dB above that required for tuned half wavelength dipoles. Table 6 indicates the enhancement required for other frequencies where shortened dipoles are used.

EXAMPLE: 20 dB + 22 dB (radiated path loss) - 110 dBm (ambient noise floor) + 20 dB (attenuator pads) + 1 dB (cable losses) - 4 dB (antenna gains) + 53 dB (enhancement) = + 2 dBm (109 dBμV).

Table 6: Enhancement figures for shortened dipoles

Frequency (MHz)	Enhancement (dB)
30	53
35	48
40	43
45	38
50	32
60	19
70	4

If the calculated level is not available then the verification can not proceed.

Once set, this signal generator output level should not be adjusted again for the entire duration of the verification process.

3) The receiving device and signal generator should be tuned to the appropriate frequency (starting at the first frequency given in the result sheet shown in table 7). The output level of the signal generator should be checked (to be certain that the original set level has been maintained) and the received level on the receiving device should be noted. For each frequency, the value to be entered in the column headed "Direct" on the results sheet is the sum of this received level plus the loss of the "in-line" adapter or cable at this frequency i.e.:

"Direct" value = received level + loss of "in-line" adapter or cable.

4) Step 3 should be repeated for all the frequencies in the results sheet shown in table 7.

Radiated attenuation: Horizontal polarization

5) The adapter used to make the direct connection between the attenuator pads should be removed and the transmit and receive dipoles connected as shown schematically in figure 17.

6) The signal generator, receiving device and dipoles should be tuned to the appropriate frequency (starting at the top of the results sheet shown in table 7).

NOTE 3: For all frequencies below 80 MHz, a shortened dipole (as defined in subclause 6.3.3) should be used. The dipole arm length is defined as the measured distance from the centre of the balun block to the tip of the arm. From a fully extended state, each telescopic element, in turn, should be "pushed in" from the tip until the required length is obtained. The outermost section needs to fully compress before any of the others, and so on.

7) The receiving dipole should be mounted on the central axis of the chamber and its phase centre should lie in the plane of symmetry of the chamber (figure 18). The dipole should be oriented for horizontal polarization.

8) The range length (3 m or 10 m) is defined as the horizontal distance between the receiving dipole and the axis of rotation of the turntable. This should be set to an accuracy of ± 0,01 m.

9) The transmitting dipole should be mounted in position 1H as shown in figures 14 and 19 and oriented for horizontal polarization. It should be positioned with its phase centre:

   a) in the plane of symmetry of the chamber (figure 18);
   b) on the axis of rotation of the turntable.

10) The output level of the signal generator should be checked (to ensure that an inadvertent change to the original set level has not occurred) and the received level on the receiving device should be noted. This value should be entered in the results sheet (table 7) under the column headed "Site".

11) Steps 6 to 10 should be repeated until all the frequencies in the results sheet have been completed, changing the dipoles as appropriate.

Table 7: Anechoic chamber verification results sheet (30 MHz to 1 000 MHz)

<table>
<tr><th colspan="6">anechoic chamber verification procedure results sheet</th><th colspan="3">30 MHz to 1 000 MHz</th></tr>
<tr><td colspan="3">Range length:
Ambient temperature:</td><td colspan="3">Polarization:
Position No.:</td><td colspan="3">Date:
Relative humidity:</td></tr>
<tr><td>Freq. (MHz)</td><td>Direct V_{direct} (dBμV)</td><td>Site V_{site} (dBμV)</td><td>Transmit Antenna factor AF_T (dB)</td><td>Receive Antenna factor AF_R (dB)</td><td>Mutual coupling correction AF_{TOT} (dB)</td><td>Overall value (dB)</td><td>Ideal value (dB)</td><td>Difference (dB)</td></tr>
<tr><td>30</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>35</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>300</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>600</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>700</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>800</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>900</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1 000</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Transmit antenna:
Transmit antenna cable:
Signal generator:
Attenuator:
Ferrite type:</td><td colspan="4">Receive antenna:
Receive antenna cable:
Receiving device:
Attenuator:
Ferrite manufacturer:</td></tr>
</table>

12) Steps 6 to 11 should be repeated with the transmitting dipole at the four other positions illustrated in figure 14 and shown as 2H, 3H, 4H and 5H in figure 19. Optionally, steps 6 to 11 should also be repeated for the four extra positions (6H, 7H, 8H and 9H).

NOTE 4: In figures 14 and 19, for both 3 m and 10 m range verification d = 0,7 m. The positioning accuracy of all positions relative to position 1H should be ± 0,01 m.

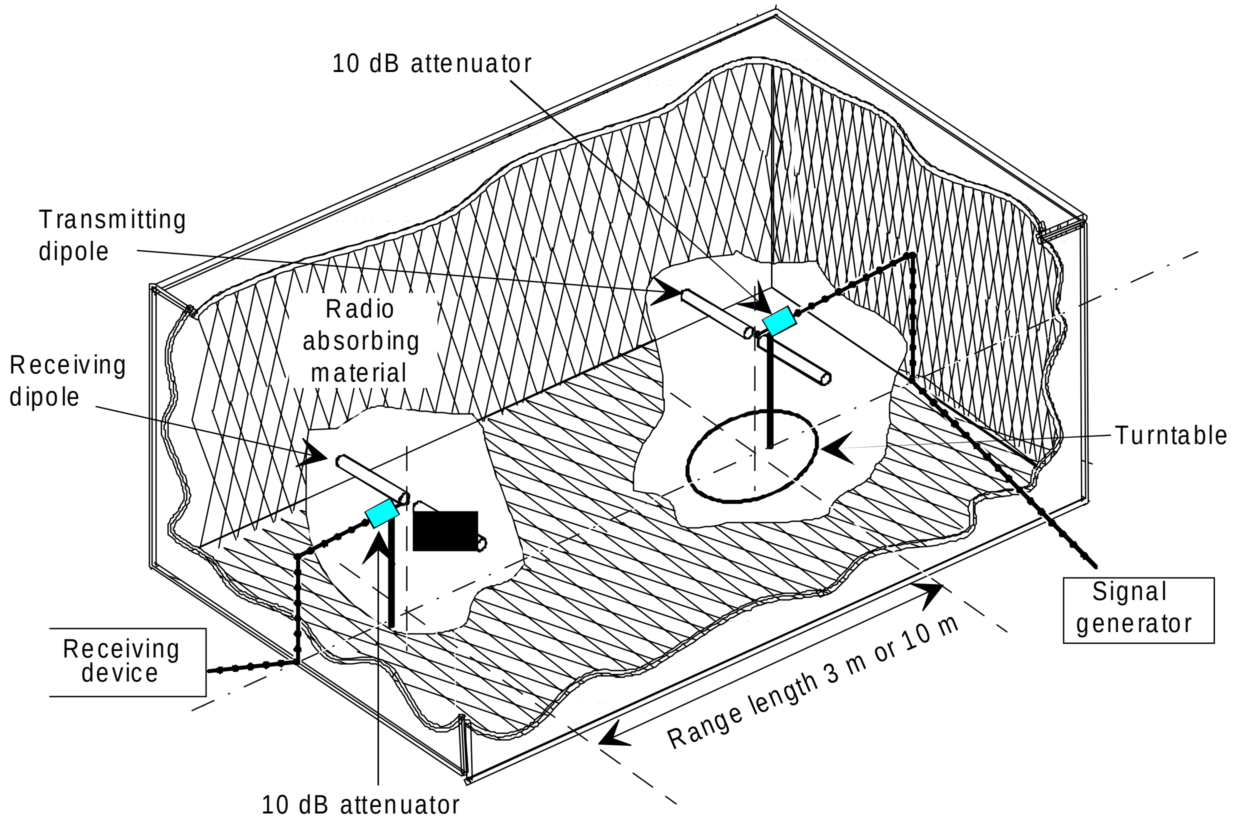

Figure 17: Equipment configuration for verification of an anechoic chamber

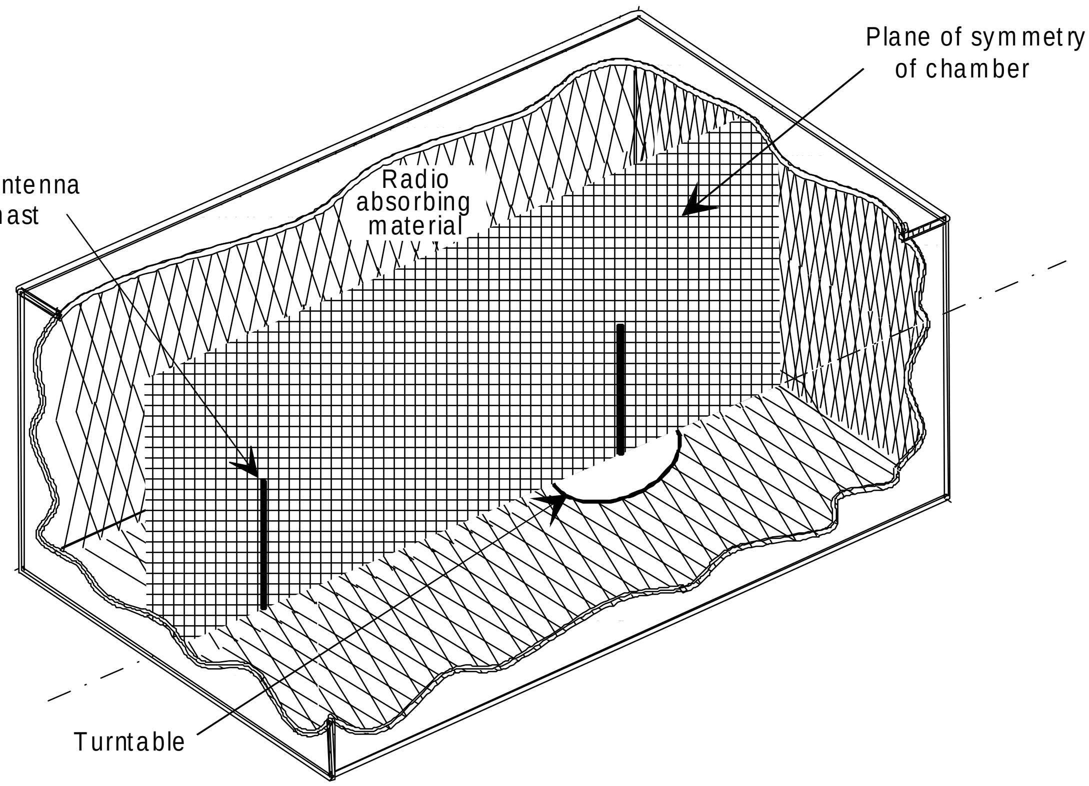

Figure 18: The plane of symmetry of the anechoic chamber

Radiated attenuation: Vertical polarization

13) The equipment should be connected as shown in figure 17 with the dipoles vertically polarized.

14) The signal generator, receiving device and dipoles should be tuned to the appropriate frequency (starting at the top of the results sheet shown in table 7).

NOTE 5: For all frequencies below 80 MHz, a shortened dipole (as defined in subclause 6.3.3) should be used. The dipole arm length is defined as the measured distance from the centre of the balun block to the tip of the arm. From a fully extended state, each telescopic element, in turn, should be "pushed in" from the tip until the required length is obtained. The outermost section needs to fully compress before any of the others, and so on.

15) The receiving dipole should be mounted on the central axis of the chamber and the whole of its body should lie in the plane of symmetry of the chamber (figure 18).

16) The range length (3 m or 10 m) is defined as the horizontal distance between the receiving dipole and the axis of rotation of the turntable. This should be set to an accuracy of ± 0,01 m.

17) The transmitting dipole should be mounted in position 1V as shown in figures 15 and 19 and the whole of its body should lie in the plane of symmetry of the chamber. Its axis should lie on the axis of rotation of the turntable.

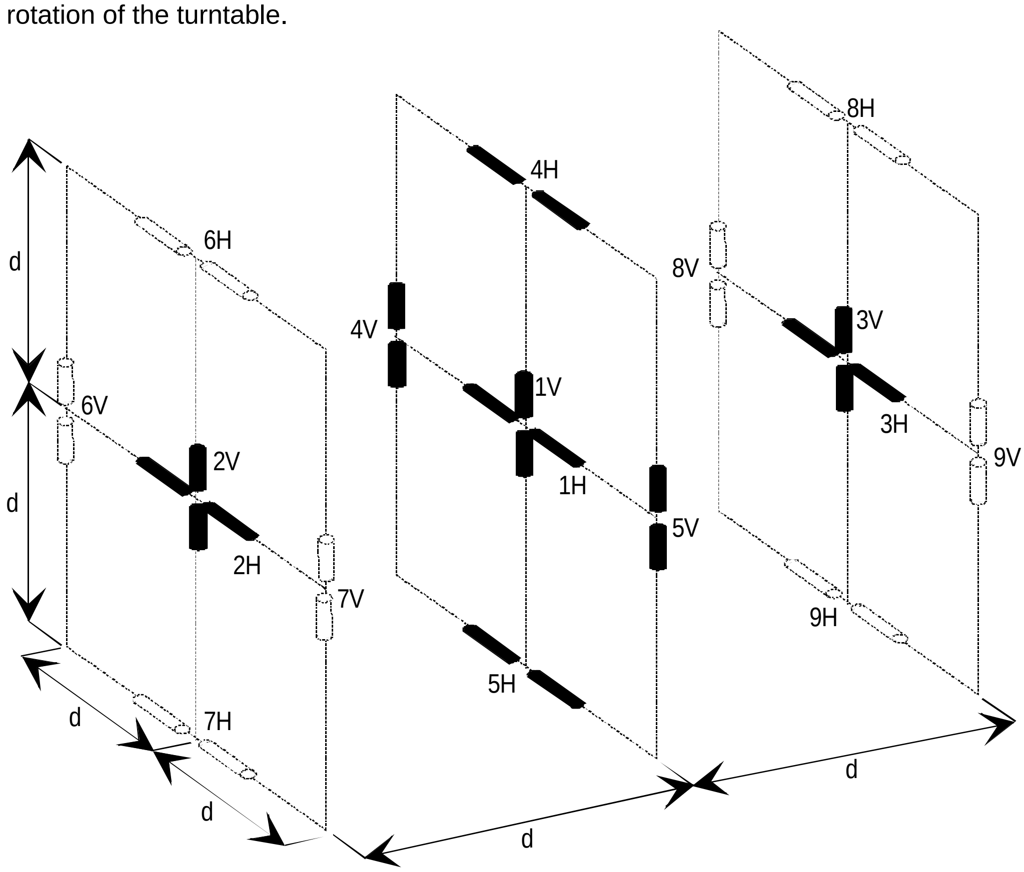

Figure 19: Expanded view of the 5 (optionally 9) transmitting dipole positions

18) The output level of the signal generator should be checked (to ensure that an inadvertent change to the original set level has not occurred) and the received level on the receiving device should be noted. This value should be entered in the result sheet (table 7) under the column headed "Site".

19) Steps 14 to 18 should be repeated until all the frequencies in the result sheet have been completed, changing the dipoles as appropriate.

20) Steps 14 to 19 should be repeated with the transmitting dipole at the four other positions as illustrated in figure 15 and shown as 2V, 3V, 4V and 5V in figure 19. Optionally, steps 14 to 19 should also be repeated for the four extra positions (6V, 7V, 8V and 9V).

NOTE 6: In figures 15 and 19, for both 3 m and 10 m range verification d = 0,7 m. The positioning accuracy of all positions relative to position 1V should be ± 0,01 m.

6.4.2 Alternative Procedure 1: 30 MHz to 1 000 MHz

The procedure contained in subclause 6.4.1 is the most accurate procedure considered for verification in the 30 MHz - 1 000 MHz band - the use of ANSI C63.5 [1] dipoles enabling precise correction figures for mutual coupling to be incorporated into the results. The procedure can be very time consuming however and, as a quicker alternative scheme, the following, less accurate procedure could be adopted.

1) The procedure, as detailed in subclause 6.4.1 should be completed for positions 1H (for horizontal polarization) and 1V (for vertical polarization).

2) Both transmitting and receiving dipoles should be replaced with bicones for the full 30 MHz - 1 000 MHz band.

NOTE 1: As a further alternative, bicones 30 MHz - 200 MHz (possibly 300 MHz) can be used with LPDAs for the rest of the band. Note, however, that the range length uncertainty associated with the moving phase centre of the latter can significantly increase measurement uncertainty (e.g. a typical design of LPDA with length approximately 1 m, could contribute a range length uncertainty of u_j = 1,73 dB over a 3 m range length. This would reduce to u_j = 0,5 dB for a 10 m range length but would remain a significant contribution to the overall uncertainty).

CAUTION: For reduced uncertainty in the verification procedure, measurements using alternative antennas should be carried out in the far-fields of the antennas (Clause 7 of ETR 273-1-1 [8]). For a typical bicone of length 1,315 m, far-field conditions over a 3 m range length only exist from 30 MHz to 60 MHz and not at 70 MHz or above. For a 10 m range length, the corresponding usable frequency range is 30 MHz to 270 MHz.

3) The entire verification procedure, as described in steps 1 - 20 of subclause 6.4.1., should be repeated including positions 1H and 1V for the transmitting antenna.

NOTE 2: This alternative procedure does not include any correction factors to account for mutual coupling effects. Whilst these effects are smaller for broadband antennas than for dipoles, there will be increased uncertainty in this alternative verification process because the effects cannot be calculated out of the measurements.

6.4.3 Procedure 2: 1 GHz to 12,75 GHz

Direct attenuation

1) Connect the two antenna cables together, including the attenuator pads via an "in-line" adapter as shown in figure 20. Alternatively, if this is not practical, a calibrated cable may be used instead of the adapter.

NOTE 1: The use of a cable will increase the overall measurement uncertainty.

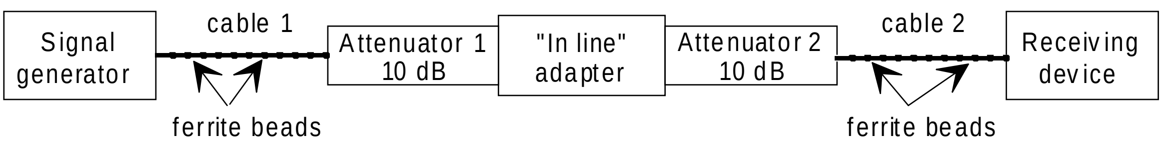

Figure 20: Initial equipment arrangement for the verification tests

2) The output of the signal generator should be adjusted to an appropriate level. The minimum acceptable level for any frequency in the band of interest may be calculated from:

- 20 dB above the maximum expected radiated path loss (20 log ((4π range length)/λ)), plus the ambient noise floor, the value of the attenuator pads and the cable losses, minus the antenna gains.

NOTE 2: For practical purposes it is advisable to set a single output level for all frequencies in the band, since this avoids level changes during the verification.

EXAMPLE: 20 dB + 75 dB (maximum expected path loss) + (- 110 dB) (ambient noise floor) + 20 dB (attenuator pads) + 15 dB (cable losses) - 10 dB (antenna gains) = +10 dBm (117 dBµV).

If the calculated level is not available then the verification cannot proceed.

Once set, this signal generator output level should not be adjusted again for the entire duration of the verification procedure.

3) The receiving device and signal generator should be tuned to the appropriate frequency (starting at the first frequency given in the result sheet shown in table 8). The output level of the signal generator should be checked (to be certain that the original set level has been maintained) and the received level on the receiving device should be noted. For each frequency, the value to be entered under the column headed "Direct" on the results sheet is the sum of this received level plus the loss of the "in-line" adapter or cable i.e.:

"Direct" value = received level + loss of "In-line" adapter or cable

4) Step 3 should be repeated for all frequencies in the results sheet shown in table 8.

Radiated attenuation: Horizontal polarization

5) The adapter used to make the direct connection between the attenuator pads should be removed and the transmit and receive antennas should be connected as shown in figure 22 with the LPDAs horizontally polarized.

NOTE 3: In order to minimize the uncertainty in range length which results from using LPDAs (the radiating phase centre moves with frequency), the radiating phase centre is defined, for the purposes of these measurements only, as the point on the log periodic central axis where its thickness is 0,08 m. This is shown in figure 21.

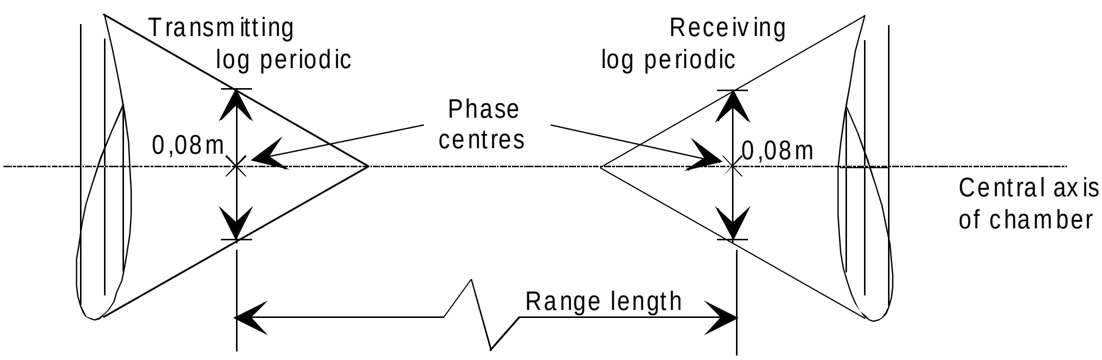

Figure 21: Definition of phase centres of the LPDA

6) The receiving antenna should be positioned with its central axis coincident with the central axis of the chamber.

7) The horizontal spacing between the phase centre of the receiving LPDA and the centre of the turntable is the range length. This should be set to an accuracy of ± 0,01 m.

8) The transmitting antenna should be mounted in position 1H as shown in figures 14 and 19, with its central axis coincident with the central axis of the chamber. The phase centre of the transmitting antenna should lie on the axis of rotation of the turntable.

9) The signal generator and receiving device should be tuned to the appropriate frequency (starting at the top of the results sheet shown in table 8).

10) The output level of the signal generator should be checked (to ensure that an inadvertent change to the original set level has not occurred) and the received level on the receiving device should be noted. This value should be entered in the results sheet (table 8) under the column headed "Site".

11) Steps 9 and 10 should be repeated until all the frequencies in the results sheet (table 8) have been completed.

12) Steps 9, 10 and 11 should be repeated with the transmitting antenna at the four other positions as illustrated in figure 14 and shown as 2H, 3H, 4H and 5H in figure 19. Optionally, steps 9, 10 and 11 should also be repeated for the four extra positions (6H, 7H, 8H and 9H).

NOTE 4: In figures 12 and 17 for both 3 and 10 m range length verifications, d = 0,7m. The positioning accuracy of the phase centres of all positions relative to position 1H should be ± 0,01 m.

NOTE 5: For all positions, both antennas needs to point directly towards each other, consistent with keeping their central axes parallel to the floor. For all transmitting positions other than 1H, 2H and 3H in figure 19, this will involve small angle rotation of both receiving and transmitting antennas. For both antennas, this rotation should be about the phase centre.

Radiated attenuation: Vertical polarization

13) The equipment should be connected as shown in figure 22.

NOTE 6: In order to minimize the uncertainty in range length which results from using LPDAs (the radiating phase centre moves with frequency), the radiating phase centre is defined, for the purposes of these measurements, as the point on the LPDA's central axis where its thickness is 0,08 m. This is shown in figure 21.

14) The receiving antenna should be positioned with its central axis coincident with the central axis of the chamber. It should be oriented for vertical polarization.

15) The horizontal spacing between the phase centre of the LPDA and the centre of the turntable is the range length. This should be set to an accuracy of ± 0,01 m.

16) The transmitting antenna should be mounted in position 1V as shown in figures 15 and 19 with its central axis coincident with the central axis of the chamber. The phase centre of the transmitting antenna should lie on the axis of rotation of the turntable. The transmitting antenna should be oriented for vertical polarization.

17) The signal generator and receiving device should be tuned to the appropriate frequency (starting at the top of the results sheet shown in table 8).

18) The output level of the signal generator should be checked (to ensure that an inadvertent change to the original set level has not occurred) and the received level on the receiving device should be noted. This value should be entered in the results sheet (table 8) under the column headed "Site".

19) Steps 17 and 18 should be repeated until all the frequencies in the results sheet (table 8) have been completed.

20) Steps 17, 18 and 19 should be repeated with the transmitting dipole at the four other positions as illustrated in figure 15 and shown as 2V, 3V, 4V and 5V in figure 19. Optionally, steps 17, 18 and 19 should also be repeated for the four extra positions (6V, 7V, 8V and 9V).

NOTE 7: In figures 13 and 17, for both 3 m and 10 m range length verifications d = 0,7 m. The positioning accuracy of the phase centres of all positions relative to position 1V should be ± 0,01 m.

NOTE 8: For all positions, both antennas needs to point directly towards each other, consistent with keeping their central axes parallel to the floor. For all transmitting positions other than 1V, 2V and 3V in figure 19, this will involve small angle rotation of both receiving and transmitting antennas. For both antennas, this rotation should be about the phase centre.

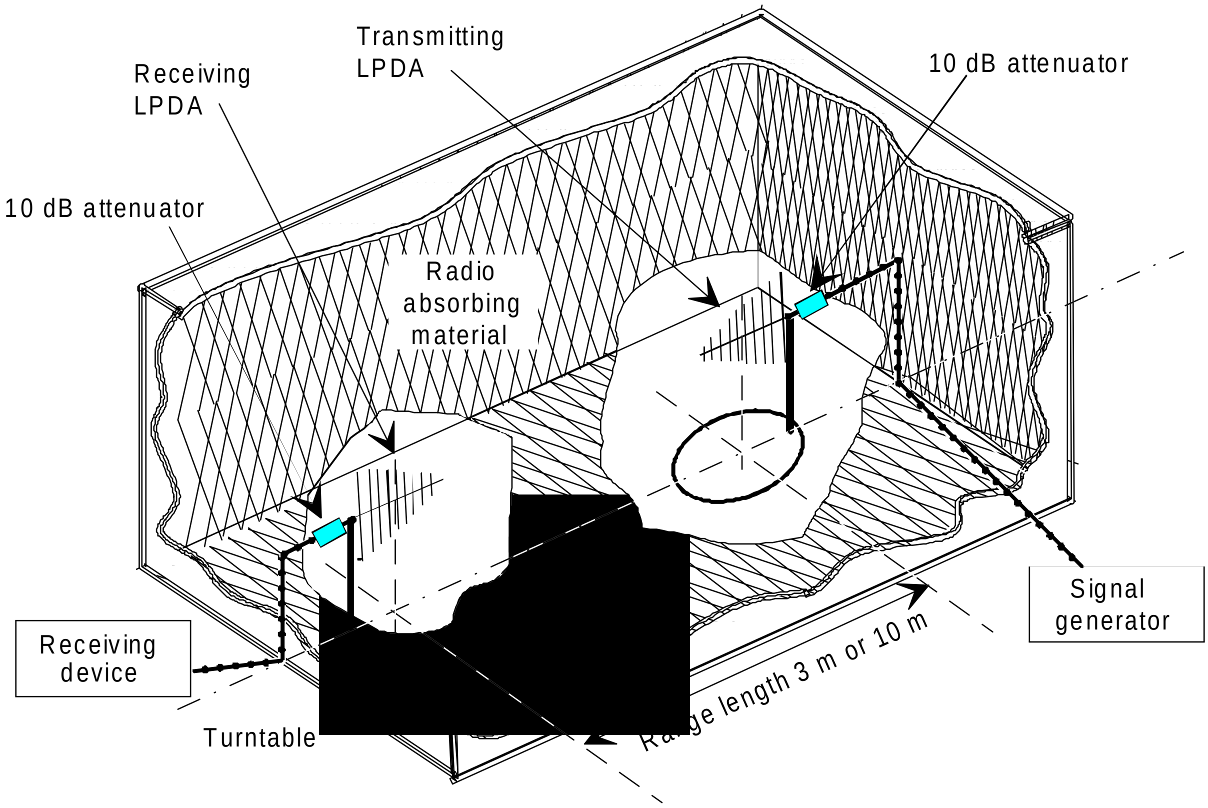

Figure 22: Anechoic chamber layout for verification with LPDAs

Table 8: Anechoic chamber verification results sheet (1 GHz - 12,75 GHz)

anechoic chamber verification procedure results sheet							1 to 12,75 GHz
Range length: Ambient temperature:			Polarization: Position No.:			Date: Relative humidity:	
Freq. (GHz)	Direct V_{direct} (dBμV)	Site V_{site} (dBμV)	Transmit Antenna factor AF_T (dB)	Receive Antenna factor AF_R (dB)	Overall value (dB)	Ideal value (dB)	Difference (dB)
1,0							
1,25							
1,5							
1,75							
2,0							
2,25							
2,5							
2,75							
3,0							
3,25							
3,5							
3,75							
4,0							
4,5							
5,0							
5,5							
6,0							
6,5							
7,0							
7,5							
8,0							
8,5							
9,0							
9,5							
10,0							
10,5							
11,0							
11,5							
12,0							
12,75							
Transmit antenna: Transmit antenna cable: Signal generator: Attenuator: Ferrite type:					Receive antenna: Receive antenna cable: Receiving device: Attenuator: Ferrite manufacturer:		

6.5 Processing the results of the verification procedure

6.5.1 Introduction

Having carried out the verification procedures as detailed in subclause 6.4 the results sheets should have values filling the first three columns, namely those headed "Freq", "Direct" and "Site". This section details the values to be incorporated in all the remaining columns.

The processing of the results finally reveals how well the measured performance of the anechoic chamber compares to the ideal case.

Firstly, the figures for entering under the column headings of "Transmit Antenna factor, AF_T" and "Receive Antenna factor, AF_R" are discussed and values are provided. Secondly, for the 30 MHz to 1 000 MHz verification procedure only, correction factors are provided for the recommended antenna scheme (ANSI C63.5 [1] dipoles) to allow for the effects of mutual coupling and mismatch loss. These effects are regarded as not significant at frequencies above 180 MHz and enable the column headed "Mutual coupling correction, AF_{TOT}" to be completed. The "Overall value" column can then be calculated. This column reveals the measured NSA for the anechoic chamber.

Finally, having extracted the relevant values (from tables provided) to complete the "Ideal value" column, the difference between the measured performance and the ideal can be calculated by simple subtraction of the values in the columns "Overall value" and "Ideal value".

6.5.2 Procedure 1: 30 MHz to 1 000 MHz

Antenna factors

For dipoles, the antenna factor of each dipole is given by:

$$Antenna\ factor = 20\ log\ f - 31{,}4\ dB$$

where f is the frequency in MHz.

NOTE 1: A resistive loss of 0,5 dB is incorporated into this formula.

Whilst the above formula for antenna factor applies only to a tuned half wavelength dipole, it should still be used in this verification procedure, even where shortened dipoles have been used (the 30 MHz - 70 MHz band). Table 9 gives the values at the test frequencies. The relevant values should be entered in the verification results sheet (table 7) in the columns headed "Transmit Antenna factor, AF_T" and "Receive Antenna factor, AF_R".

NOTE 2: Table 9 applies for both horizontal and vertical polarization

When antennas other than dipoles are used, antenna factors are usually provided by the manufacturers. Where gain figures, rather than antenna factors, have been given, these can be converted into antenna factor by the following equation:

$$Antenna\ factor\ =\ 20\log\left(\frac{9{,}734}{\lambda\sqrt{G}}\right)\text{dB}$$

where:

λ is the wavelength (m);
G is the numeric gain.

NOTE 3: The gain figure to be used should be relative to an isotropic radiator - not relative to a dipole.

Table 9: Antenna factor for a dipole used in the verification procedure.

Frequency (MHz)	Antenna factor (dB)
30	-1,9
35	-0.5
40	0,6
45	1,7
50	2,6
60	4,2
70	5,5
80	6,7
90	7,7
100	8,6
120	10,2
140	11,5

Frequency (MHz)	Antenna factor (dB)
160	12,7
180	13,7
200	14,6
250	16,6
300	18,1
400	20,6
500	22,6
600	24,2
700	25,5
800	26,7
900	27,7
1 000	28,6

Mutual coupling and mismatch loss correction factors

Table 10 give the factors necessary to correct the measured figures not only for mutual coupling, but also for mismatch transmission loss - this being the dominant term for frequencies up to 70 MHz. The table applies for both vertical and horizontal polarization.

NOTE 4: Particularly at low frequencies (i.e. up to 180 MHz) the performance of each antenna used in the verification procedure is affected by the presence of the other antenna. This interaction between antennas is termed mutual coupling and has been modelled by computer simulation for the recommended antenna scheme (ANSI dipoles) only.

For the recommended dipole antenna scheme only, the relevant figures should be taken from table 10 and entered in the results sheet (table 7) in the column headed "Mutual coupling correction AF_{TOT}". For all frequencies above 180 MHz, the correction factor should be taken as 0,0 dB.

For the alternative antenna schemes (bicones only or bicones and log periodics) all entries in the "Mutual coupling correction AF_{TOT}" column should be 0,0 dB.

Table 10: Mutual coupling and mismatch loss correction factors

	Range lengths and transmitting dipole positions:											
	Range length: 3 m Various positions						Range length: 10 m Various positions					
Freq (MHz)	**1H 1V**	**2H 2V**	**3H 3V**	**4H,4V 5H,5V**	**6H,6V 7H,7V**	**8H,8V 9H,9V**	**1H 1V**	**2H 2V**	**3H 3V**	**4H,4V 5H,5V**	**6H,6V 7H,7V**	**8H,8V 9H,9V**
30	52,7	53,3	52,3	52,6	53,1	52,3	51,5	51,5	51,5	51,5	51,5	51,5
35	47,5	48,1	47,1	47,4	48,0	47,1	46,5	46,5	46,4	46,5	46,5	46,4
40	42,4	42,9	42,1	42,3	42,8	42,0	41,5	41,5	41,5	41,5	41,5	41,5
45	37,1	37,6	36,8	37,1	37,5	36,8	36,3	36,3	36,3	36,3	36,3	36,3
50	31,5	31,9	31,2	31,4	31,8	31,2	30,7	30,8	30,7	30,7	30,8	30,7
60	18,7	19,1	18,5	18,7	19,0	18,5	18,1	18,1	18,1	18,1	18,1	18,1
70	3,8	4,4	3,6	3,7	4,3	3,6	3,2	3,3	3,3	3,3	3,3	3,3
80	0,7	1,0	0,7	0,9	0,9	0,7	0,2	0,3	0,2	0,2	0,3	0,2
90	0,6	0,9	0,3	0,6	0,5	0,3	0,1	0,0	0,0	0,1	0,0	0,0
100	0,6	0,5	0,2	0,5	0,5	0,2	0,1	0,1	0,1	0,1	0,1	0,1
120	0,3	0,8	0,5	0,3	0,8	0,4	0,2	0,2	0,2	0,2	0,2	0,2
140	0,5	0,6	0,4	0,2	0,5	0,3	0,2	0,2	0,2	0,2	0,2	0,3
160	0,4	0,4	0,4	0,4	0,4	0,4	0,3	0,3	0,2	0,3	0,3	0,3
180	0,3	0,5	0,3	0,3	0,5	0,3	0,2	0,2	0,2	0,2	0,2	0,2

Completion of the results sheet

The next stage is to enter values in the column headed "Overall value". This is achieved by performing the following calculation:

$$\text{"Overall value"} = \text{"}V_{direct}\text{"} - V_{site}\text{"} - \text{"} AF_T \text{"} - \text{"} AF_R\text{"} - \text{"} AF_{TOT}\text{"}$$

The resulting value is the measured NSA for the anechoic chamber.

The final stages in determining the quality of the site are to complete the column headed "Ideal value" in the results sheet (table 7) by taking the relevant values from table 11 and to calculate the entries for the "Difference" column from:

$$\text{"Difference"} \quad \text{"Overall value"} - \text{"Ideal value"}$$

The values in the "Difference" column represent the variation between the theoretical and the measured NSA of the anechoic chamber.

Table 11: Theoretical ideal values for NSA

	Ideal NSA (dB)											
	Range length: 3 m Various positions						Range length: 10 m Various positions					
Freq. (MHz)	**1H 1V**	**2H 2V**	**3H 3V**	**4H,4V 5H,5V**	**6H,6V 7H,7V**	**8H,8V 9H,9V**	**1H 1V**	**2H 2V**	**3H 3V**	**4H,4V 5H,5V**	**6H,6V 7H,7V**	**8H,8V 9H,9V**
30	12,0	9,7	13,8	12,2	10,1	14,0	22,5	21,8	23,1	22,5	21,9	23,1
35	10,7	8,4	12,5	10,9	8,7	12,6	21,1	20,5	21,7	21,1	20,5	21,7
40	9,5	7,2	11,3	9,7	7,6	11,5	20,0	19,3	20,6	20,0	19,4	20,6
45	8,5	6,2	10,3	8,7	6,6	10,5	19,0	18,3	19,5	19,0	18,3	19,5
50	7,6	5,3	9,4	7,8	5,6	9,5	18,0	17,4	18,6	18,0	17,4	18,6
60	6,0	3,7	7,8	6,2	4,1	8,0	16,4	15,8	17,0	16,5	15,8	17,0
70	4,6	2,3	6,5	4,9	2,7	6,6	15,1	14,5	15,7	15,1	14,5	15,7
80	3,5	1,2	5,3	3,7	1,6	5,5	13,9	13,3	14,5	14,0	13,3	14,6
90	2,5	0,2	4,3	2,7	0,5	4,4	12,9	12,3	13,5	13,0	12,3	13,5
100	1,5	-0,8	3,4	1,8	-0,4	3,5	12,0	11,4	12,6	12,0	11,4	12,6
120	0,0	-2,4	1,8	0,2	-2,0	1,9	10,4	9,8	11,0	10,4	9,8	11,0
140	-1,4	-3,7	0,4	-1,2	-3,3	0,6	9,1	8,5	9,7	9,1	8,5	9,7
160	-2,5	-4,9	-0,7	-2,3	-4,5	-0,6	7,9	7,3	8,5	8,0	7,3	8,5
180	-3,6	-5,9	-1,7	-3,3	-5,5	-1,6	6,9	6,3	7,5	7,0	6,3	7,5
200	-4,5	-6,8	-2,7	-4,3	-6,4	-2,5	6,0	5,4	6,6	6,0	5,4	6,6
250	-6,4	-8,7	-4,6	-6,2	-8,3	-4,4	4,0	3,4	4,6	4,1	3,4	4,7
300	-8,0	-10,3	-6,2	-7,8	-9,9	-6,0	2,5	1,8	3,1	2,5	1,9	3,1
400	-10,5	-12,8	-8,7	-10,3	-12,4	-8,5	-0,0	-0,7	0,6	0,0	-0,7	0,6
500	-12,4	-14,7	-10,6	-12,2	-14,4	-10,5	-2,0	-2,6	-1,4	-2,0	-2,6	-1,4
600	-14,0	-16,3	-12,2	-13,8	-15,9	-12,1	-3,6	-4,2	-3,0	-3,5	-4,2	-3,0
700	-15,4	-17,7	-13,5	-15,1	-17,3	-13,4	-4,9	-5,5	-4,3	-4,9	-5,5	-4,3
800	-16,5	-18,8	-14,7	-16,3	-18,4	-14,5	-6,1	-6,7	-5,5	-6,0	-6,7	-5,5
900	-17,5	-19,9	-15,7	-17,3	-19,5	-15,6	-7,1	-7,7	-6,5	-7,1	-7,7	-6,5
1 000	-18,5	-20,8	-16,6	-18,2	-20,4	-16,5	-8,0	-8,6	-7,4	-8,0	-8,6	-7,4

6.5.3 Procedure 2 (1 GHz to 12,75 GHz)

Antenna factors

Generally, the manufacturers of the LPDAs will supply figures for either the gain or antenna factor variation with frequency. Where the gain variation is given, this should be converted to antenna factor by the following formula:

$$Antenna\ factor = 20\log\left(\frac{9{,}734}{\lambda\sqrt{G}}\right)\mathrm{dB}$$

where:
- λ is the wavelength (m);
- G is the numeric gain.

NOTE: The gain figure to be used should be relative to an isotropic radiator - not relative to a dipole.

Whether directly or indirectly (by using this formula), the antenna factor columns in the results sheet headed "Transmit Antenna factor, AF_T" and "Receive Antenna factor, AF_R" should now be filled in with the relevant values.

Completion of the results sheet

The next stage is to fill in the column headed "Overall value". The relevant values are determined by subtracting the values in the "Site, V_{site}", "Transmit Antenna factor, AF_T" and "Receive Antenna factor, AF_R" columns from the values in the "Direct, V_{direct}" column i.e.:

$$\text{"Overall value"} = \text{"}V_{direct}\text{"} - \text{"}V_{site}\text{"} - \text{"}AF_T\text{"} - \text{"}AF_R\text{"}$$

The resulting value is the measured NSA for the anechoic chamber.

The final stages in determining the quality of the chamber are to complete the column headed "Ideal value" in the results sheet by taking the relevant values from table 12 and to calculate the entries for the "Difference" column from:

$$\text{"Difference"} = \text{"Overall value"} - \text{"Ideal value"}$$

The resulting values in the "Difference" column represent the variation between the ideal and the measured performance of the anechoic chamber.

Table 12: Theoretical ideal values for NSA

	Ideal NSA (dB)											
	Range length: 3 m Various positions						Range length: 10 m Various positions					
Freq. (GHz)	**1H 1V**	**2H 2V**	**3H 3V**	**4H,4V 5H,5V**	**6H,6V 7H,7V**	**8H,8V 9H,9V**	**1H 1V**	**2H 2V**	**3H 3V**	**4H,4V 5H,5V**	**6H,6V 7H,7V**	**8H,8V 9H,9V**
1	-18,5	-20,8	-16,6	-18,2	-20,4	-16,5	-8,0	-8,6	-7,4	-8,0	-8,6	-7,4
1,25	-20,4	-22,7	-18,6	-20,0	-22,3	-18,4	-9,9	-10,6	-9,4	-9,9	-10,5	-9,3
1,5	-22,0	-24,3	-20,2	-21,7	-23,9	-20,0	-11,5	-12,2	-10,9	-11,5	-12,1	-10,9
1,75	-23,3	-25,6	-21,5	-23,1	-25,2	-21,3	-12,9	-13,5	-12,3	-12,8	-13,5	-12,3
2	-24,5	-26,8	-22,7	-24,2	-26,4	-22,5	-14,0	-14,7	-13,4	-14,0	-14,6	-13,4
2,25	-25,5	-27,8	-23,7	-25,3	-27,4	-23,5	-15,0	-15,7	-14,5	-15,0	-15,6	-14,4
2,5	-26,4	-28,7	-24,6	-26,2	-28,3	-24,4	-16,0	-16,6	-15,4	-15,9	-16,6	-15,4
2,75	-27,2	-29,6	-25,4	-27,0	-29,2	-25,3	-16,8	-17,4	-16,2	-16,8	-17,4	-16,2
3	-28,0	-30,3	-26,2	-27,8	-29,9	-26,0	-17,5	-18,2	-17,0	-17,5	-18,1	-16,9
3,25	-28,7	-31,0	-26,9	-28,5	-30,6	-26,7	-18,2	-18,9	-17,6	-18,2	-18,8	-17,6
3,5	-29,3	-31,6	-27,5	-29,1	-31,3	-27,4	-18,9	-19,5	-18,3	-18,9	-19,5	-18,3
3,75	-29,9	-32,2	-28,1	-29,7	-31,9	-28,0	-19,5	-20,1	-18,9	-19,5	-20,1	-18,9
4	-30,5	-32,8	-28,7	-30,3	-32,4	-28,5	-20,0	-20,7	-19,5	-20,0	-20,6	-19,4
4,5	-31,5	-33,8	-29,7	-31,3	-33,4	-29,5	-21,1	-21,7	-20,5	-21,0	-21,7	-20,5
5	-32,4	-34,7	-30,6	-32,2	-34,4	-30,5	-22,0	-22,6	-21,4	-22,0	-22,6	-21,4
5,5	-33,3	-35,6	-31,4	-33,0	-35,2	-31,3	-22,8	-23,4	-22,2	-22,8	-23,4	-22,2
6	-34,0	-36,3	-32,2	-33,8	-35,9	-32,0	-23,6	-24,2	-23,0	-23,5	-24,2	-23,0
6,5	-34,7	-37,0	-32,9	-34,5	-36,6	-32,7	-24,3	-24,9	-23,7	-24,3	-24,9	-23,7
7	-35,4	-37,7	-33,5	-35,1	-37,3	-33,4	-24,9	-25,5	-24,3	-24,9	-25,5	-24,3
7,5	-36,0	-38,3	-34,1	-35,7	-37,9	-34,0	-25,5	-26,1	-24,9	-25,5	-26,1	-24,9
8	-36,5	-38,8	-34,7	-36,3	-38,4	-34,5	-26,1	-26,7	-25,5	-26,0	-26,7	-25,5
8,5	-37,0	-39,4	-35,2	-36,8	-39,0	-35,1	-26,6	-27,2	-26,0	-26,6	-27,2	-26,0
9	-37,5	-39,8	-35,7	-37,3	-39,5	-35,6	-27,1	-27,7	-26,5	-27,1	-27,7	-26,5
9,5	-38,0	-40,3	-36,2	-37,8	-39,9	-36,0	-27,6	-28,2	-27,0	-27,5	-28,2	-26,9
10	-38,5	-40,8	-36,6	-38,2	-40,0	-36,5	-28,0	-28,6	-27,4	-28,0	-28,6	-27,4
10,5	-38,9	-41,2	-37,1	-38,7	-40,8	-36,9	-28,4	-29,1	-27,8	-28,4	-29,0	-27,8
11	-39,3	-41,6	-37,5	-39,1	-41,2	-37,3	-28,8	-29,5	-28,2	-28,8	-29,4	-28,2
11,5	-39,7	-42,0	-37,8	-39,4	-41,6	-37,7	-29,2	-29,8	-28,6	-29,2	-29,8	-28,6
12	-40,0	-42,3	-38,2	-39,8	-42,0	-38,1	-29,6	-30,2	-29,0	-29,6	-30,2	-29,0
12,75	-40,6	-42,9	-38,7	-40,3	-42,5	-38,6	-30,1	-30,7	-29,5	-30,1	-30,7	-29,5

6.5.4 Report format

It is suggested that the results of the verification are presented in two ways, firstly in the format of a completed results sheet, and secondly in the form of a plot of the "Difference" column against frequency for each polarization as shown in figure 23.

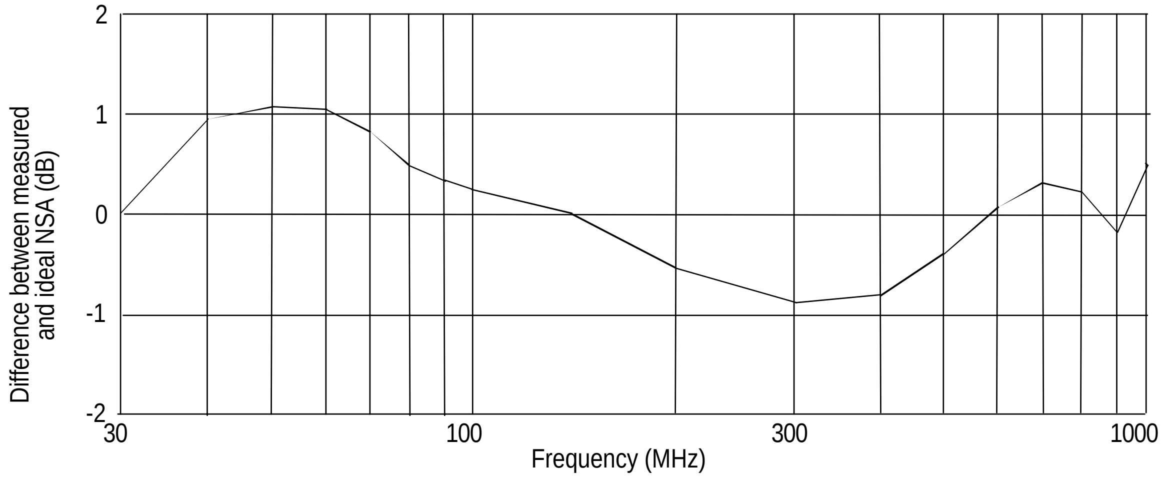

Figure 23: Plot of the difference between the measured and ideal NSA against frequency

6.6 Calculation of measurement uncertainty (Procedure 1)

The column headed "Overall" in the results sheet is completed during the processing of the results for the verification procedure. The values entered in this column are the measured NSA figures for the anechoic chamber.

The value, at any particular frequency, for the measured NSA is "Direct" (reference value) less "Site" (the value appearing on the receiver during the measurement) less the sum of "Transmit Antenna factor AF_T", "Receive Antenna factor AF_R" and "Mutual coupling correction AF_{TOT}" i.e.:

NSA = "Direct" - "Site" - "Transmit Antenna factor " - "Receive Antenna factor " - "Mutual coupling correction"

As an example, let the direct attenuation be +10 dBm and the received level during the site measurement be -33 dBm. Putting both the antenna factors at 3,9 dB and the mutual coupling correction at 2,1 dB gives a measured NSA value of:

NSA = (10 dBm - (-33 dBm)) - (3,9 dB + 3,9 dB + 2,1 dB) = 33,1 dB

There are uncertainties in each of these components for the NSA and an example of a typical calculation of the expanded uncertainty is now given. A fully worked example calculation can be found in clause 4 of ETR 273-1-2 [9].

6.6.1 Uncertainty contribution, direct attenuation measurement

The verification procedure involves two different measurement stages and the derivation of NSA. The first stage (the reference) is with all the items of test equipment connected directly together via an adapter between the attenuators as shown in figure 24 (components shown shaded are common to both stages of the procedure).

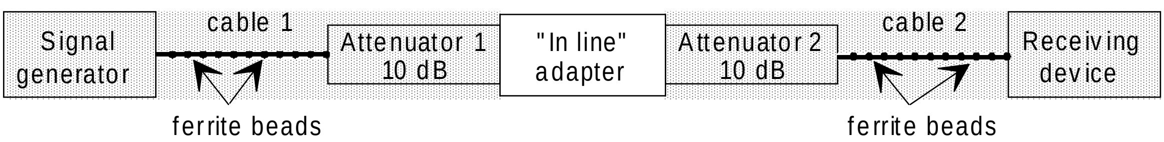

Figure 24: Stage 1: Direct attenuation measurement for the verification procedure

Despite the commonality of most of the components to both stages of this procedure, the mismatch uncertainty contribution from both stages has to be calculated and included in the uncertainty calculations, since the load conditions vary i.e. antennas replace the adapter in the second stage. Conversely, as a result of this commonality, the uncertainty contribution of some of the individual components will cancel.

The magnitude of the random uncertainty contribution to this stage of the procedure can be assessed from multiple repetition of the direct attenuation measurement. All the uncertainty components which contribute to this stage of the test are listed in table 13. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 13: Contributions from the direct attenuation measurement

uj or i	Description of uncertainty contributions	dB
u_{j35}	*mismatch: direct attenuation measurement*	
u_{j38}	*signal generator: absolute output level*	
u_{j39}	*signal generator: output level stability*	
u_{j19}	*cable factor: receiving antenna*	0,00
u_{j19}	*cable factor: transmitting antenna*	0,00
u_{j41}	*insertion loss: receiving antenna cable*	0,00
u_{j41}	*insertion loss: transmitting antenna cable*	0,00
u_{j40}	*insertion loss: receiving antenna attenuator*	0,00
u_{j40}	*insertion loss: transmitting antenna attenuator*	0,00
u_{j42}	*insertion loss: adapter*	
u_{j47}	*receiving device: absolute level*	0,00
u_{j48}	*receiving device: linearity*	0,00
u_{i01}	*random uncertainty*	

The standard uncertainties from table 13 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ direct\ attenuation\ measurement}$) for the direct attenuation measurement in dB.

6.6.2 Uncertainty contribution, NSA measurement

This stage involves removing the adapter and connecting each attenuator to an antenna as shown in figure 25, and recording the new level on the receiving device.

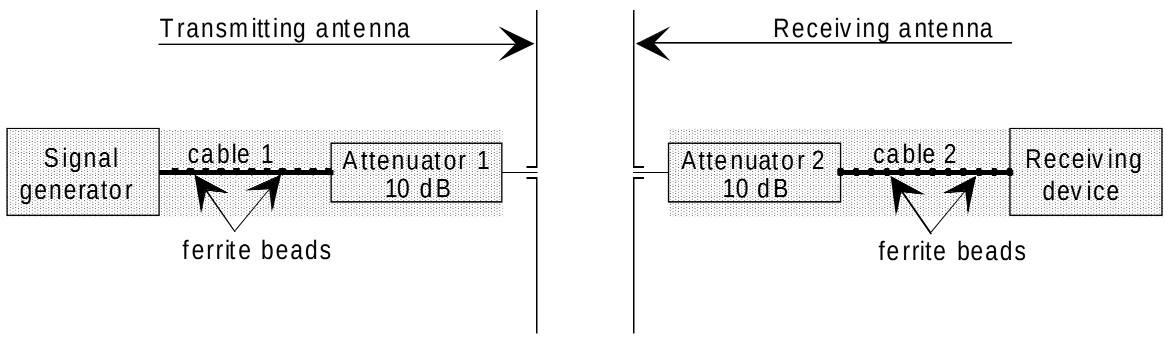

Figure 25: Stage 2: NSA measurement

The difference in received levels (after allowance for any correction factors which may be appropriate), for the same signal generator output level, reveals the NSA. All the uncertainty components which contribute to this stage of the test are listed in table 14. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 14: Contributions from the NSA measurement

uj or I	Description of uncertainty contributions	dB
u_{j36}	*mismatch: transmitting part*	
u_{j37}	*mismatch: receiving part*	
u_{j38}	*signal generator: absolute output level*	
u_{j39}	*signal generator: output level stability*	
u_{j19}	*cable factor: receiving antenna*	
u_{j19}	*cable factor: transmitting antenna*	
u_{j41}	*insertion loss: receiving antenna cable*	0,00
u_{j41}	*insertion loss: transmitting antenna cable*	0,00
u_{j40}	*insertion loss: receiving antenna attenuator*	0,00
u_{j40}	*insertion loss: transmitting antenna attenuator*	0,00
u_{j47}	*receiving device: absolute level*	
u_{j48}	*receiving device: linearity*	
u_{j16}	*range length*	
u_{j03}	*reflectivity of absorber material: transmitting antenna to the receiving antenna*	
u_{j44}	*antenna: antenna factor of the receiving antenna*	
u_{j44}	*antenna: antenna factor of the transmitting antenna*	
u_{j46}	*antenna: tuning of the receiving antenna*	
u_{j46}	*antenna: tuning of the transmitting antenna*	
u_{j22}	*position of the phase centre: receiving antenna*	
u_{j22}	*position of the phase centre: transmitting antenna*	
u_{j07}	*mutual coupling: transmitting antenna to its images in the absorbing material*	
u_{j07}	*mutual coupling: receiving antenna to its images in the absorbing material*	
u_{j10}	*mutual coupling: transmitting antenna to the receiving antenna*	
u_{j12}	*mutual coupling: interpolation of mutual coupling and mismatch loss correction factors*	
u_{j34}	*ambient effect*	
u_{i01}	*random uncertainty*	

The standard uncertainties from table 14 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ NSA\ measurement}$) for the NSA measurement in dB.

6.6.3 Expanded uncertainty of the verification procedure

The combined standard uncertainty of the results of the verification procedure is the combination of the components outlined in subclauses 6.6.1 and 6.6.2. The components to be combined are: $u_{c\ direct\ attenuation\ measurement}$ and $u_{c\ NSA\ measurement}$

$$u_c = \sqrt{u_{c\,direct\,attenuation\,measurement}^2 + u_{c\,NSA\,measurement}^2} = \_\_,\_\_\,\mathrm{dB}$$

The expanded uncertainty is ±1,96 × u_c = ± __,__ dB at a 95 % confidence level.

6.7 Calculation of measurement uncertainty (Procedure 2)

The column headed "Overall" in the results sheet is completed during the processing of the results for the verification procedure. The values entered in this column are the measured NSA figures for the anechoic chamber.

The value, at any particular frequency, for the measured NSA is "Direct" (reference value) less "Site" (the value appearing on the receiver during the NSA measurement) less the sum of "Transmit Antenna factor AF_T" and "Receive Antenna factor AF_R" i.e.:

NSA = "Direct" - "Site" - "Transmit Antenna factor" - "Receive Antenna factor"

As an example, let the direct attenuation value be 10 dBm and the received level during the site measurement be -33 dBm. Putting each antenna factor at 3,9 dB gives a measured NSA value of:

NSA = [10 dBm - (-33 dBm)] - (7,8 dB) = 35,2 dB

There are uncertainties in each of these components for the NSA and an example of a typical calculation of the expanded uncertainty is now given. A fully worked example calculation can be found in clause 4 of ETR 273-1-2 [9].

6.7.1 Uncertainty contribution, direct attenuation measurement

The verification procedure involves two different measurement stages and the derivation of NSA. The first stage (the reference) is with all the items of test equipment connected directly together via an adapter between the attenuators as shown in figure 26 (components shown shaded are common to both stages of the procedure).

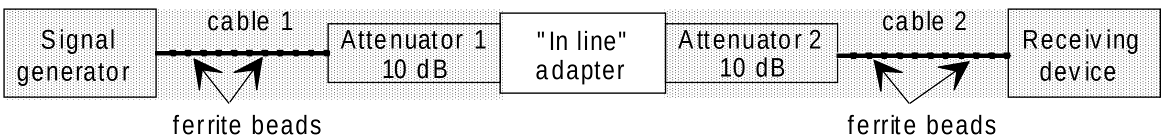

Figure 26: Stage 1: Direct attenuation measurement for the verification procedure

Despite the commonality of most of the components to both stages of this procedure, the mismatch uncertainty contribution for both stages of the test has to be calculated and included in the uncertainty calculations. This is the result of load conditions varying (i.e. antennas replacing the adapter in the second stage). Conversely, as a result of this commonality, the uncertainty contributions of some of the individual components will cancel.

The magnitude of the random uncertainty contribution to each stage of the procedure can be assessed from multiple repetition of the respective measurements. All the uncertainty components which contribute to this stage of the test are listed in table 15. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 15: Contributions from the direct attenuation measurement

uj or i	Description of uncertainty contributions	dB
u_{j35}	*mismatch: direct attenuation measurement*	
u_{j38}	*signal generator: absolute output level*	0,00
u_{j39}	*signal generator: output level stability*	
u_{j19}	*cable factor: receiving LPDA*	0,00
u_{j19}	*cable factor: transmitting LPDA*	0,00
u_{j41}	*insertion loss: receiving LPDA cable*	0,00
u_{j41}	*insertion loss: transmitting LPDA cable*	0,00
u_{j40}	*insertion loss: receiving LPDA attenuator*	0,00
u_{j40}	*insertion loss: transmitting LPDA attenuator*	0,00
u_{j42}	*insertion loss: adapter*	
u_{j47}	*receiving device: absolute level*	0,00
u_{j48}	*receiving device: linearity*	0,00
u_{i01}	*random uncertainty*	

The standard uncertainties from table 15 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ direct\ attenuation\ measurement}$) for the direct attenuation measurement in dB.

6.7.2 Uncertainty contribution, NSA measurement

This stage involves removing the adapter and connecting each attenuator to an antenna as shown in figure 27, and recording the new level on the receiving device.

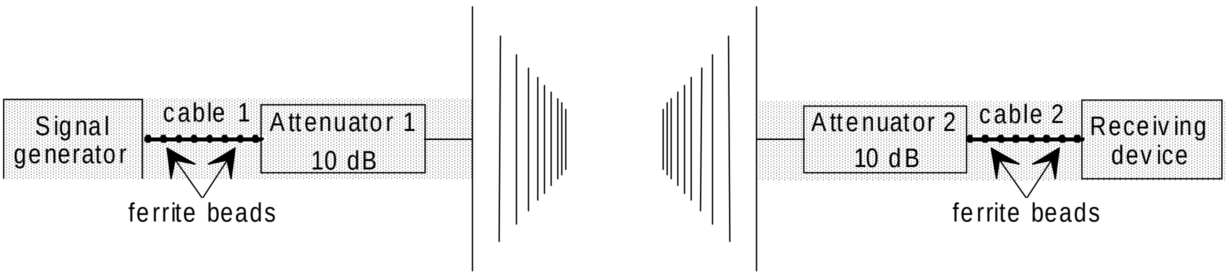

Figure 27: Stage 2: NSA measurement

The difference in received levels (after allowance for any correction factors which may be appropriate), for the same signal generator output level, reveals the NSA. All the components which contribute to this stage of the test are listed in table 16. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 16: Contributions from the measurement

uj or i	Description of uncertainty contributions	dB
u_{j36}	*mismatch: transmitting part*	
u_{j37}	*mismatch: receiving part*	
u_{j38}	*signal generator: absolute output level*	0,00
u_{j39}	*signal generator: output level stability*	
u_{j19}	*cable factor: receiving LPDA*	
u_{j19}	*cable factor: transmitting LPDA*	
u_{j41}	*insertion loss: receiving LPDA cable*	0,00
u_{j41}	*insertion loss: transmitting LPDA cable*	0,00
u_{j40}	*insertion loss: receiving LPDA attenuator*	0,00
u_{j40}	*insertion loss: transmitting LPDA attenuator*	0,00
u_{j47}	*receiving device: absolute level*	
u_{j48}	*receiving device: linearity*	
u_{j16}	*range length*	0,00
u_{j03}	*reflectivity of absorber material: transmitting antenna to the receiving antenna*	
u_{j44}	*antenna: antenna factor of the receiving LPDA*	
u_{j44}	*antenna: antenna factor of the transmitting LPDA*	
u_{j22}	*position of the phase centre: receiving LPDA*	
u_{j22}	*position of the phase centre: transmitting LPDA*	
u_{j23}	*position of the phase centre: LPDA*	
u_{j07}	*mutual coupling: receiving LPDA and its images in the absorbing material*	
u_{j07}	*mutual coupling: transmitting LPDA and its images in the absorbing material*	
u_{j34}	*ambient effect*	0,00
u_{i01}	*random uncertainty*	

The standard uncertainties from table 16 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ NSA\ measurement}$) for the NSA measurement of in dB.

6.7.3 Expanded uncertainty of the verification procedure

The combined standard uncertainty of the results of the verification procedure is the combination of the components outlined in subclauses 6.7.1 and 6.7.2. The components to be combined are $u_{c\ direct\ attenuation\ measurement}$ and $u_{c\ NSA\ measurement}$.

$$u_c = \sqrt{u^2_{c\,direct\,attenuation\,measurement} + u^2_{c\,NSA measurement}} = \_\_,\_\_\,\mathrm{dB}$$

The expanded uncertainty is ± 1,96 x u_c = ± __,__ dB at a 95 % confidence level.

6.8 Summary

The expanded uncertainty values derived in subclauses 6.6.3 and 6.7.3 reveal the uncertainty with which the NSA can be measured. Any value of NSA which varies by more than these uncertainty values from the theoretical value is probably due to imperfection(s) in the site. These imperfections may be due to reflections from a range of possible sources in the anechoic chamber at the time the verification procedure is carried out.

7 Test methods

7.1 Introduction

The following test methods apply to integral antenna devices only i.e. EUTs not fitted with either a permanent or a temporary external antenna connector. The Spurious emissions test also applies to EUTs with a detachable antenna.

The range length of the anechoic chamber should be adequate to allow for testing in the far-field of the EUT i.e. the range length should be equal to or exceed:

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

where:

d_1 is the largest dimension of the EUT/dipole after substitution (m);

d_2 is the largest dimension of the test antenna (m);

λ is the test frequency wavelength (m).

It should be noted that in the substitution part of these tests, where both test and substitution/measuring antennas are half wavelength dipoles, this minimum range length for far-field testing would be (2λ).

It should be stated in the test report when either of these conditions is not met. The additional contributions to the measurement uncertainty which result can be incorporated into the analysis of the results.

No part of the volume of the EUT should, at any angle of rotation, fall outside the "quiet zone" of the chamber at the nominal frequency of test. Where this condition cannot be met, the measurement should not be carried out.

NOTE: The "quiet zone" is a volume within the chamber 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.

An additional requirement of the chamber construction is to ensure that no part of any antenna or EUT should come within 1 m of the absorbing panels (this is to avoid "electrical loading"). For the EUT, this condition needs to be satisfied for all angles of rotation. Where this condition cannot be met, the measurement should not be carried out.

Further, measurements should not be carried out if the reflectivity of the absorbing material within the chamber is worse than - 5 dB at the frequency of test.

7.1.1 Site preparation

The cables for both ends of the test chamber should be routed behind and away from the antennas, parallel to the side walls and floor of the chamber, towards the back walls for a minimum of 2 m (unless the back wall is reached). They should then be allowed to drop vertically towards the floor, preferably behind the anechoic panels, and routed out through the screen (normally via a breakout panel) to the test equipment.

These cables should be dressed with ferrite beads, spaced 0,15 m apart for their entire lengths within the screen of the chamber. The routeing and dressing of the cables should be identical to the verification procedure set-up.

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

The calibration data for all cables and attenuators used 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.

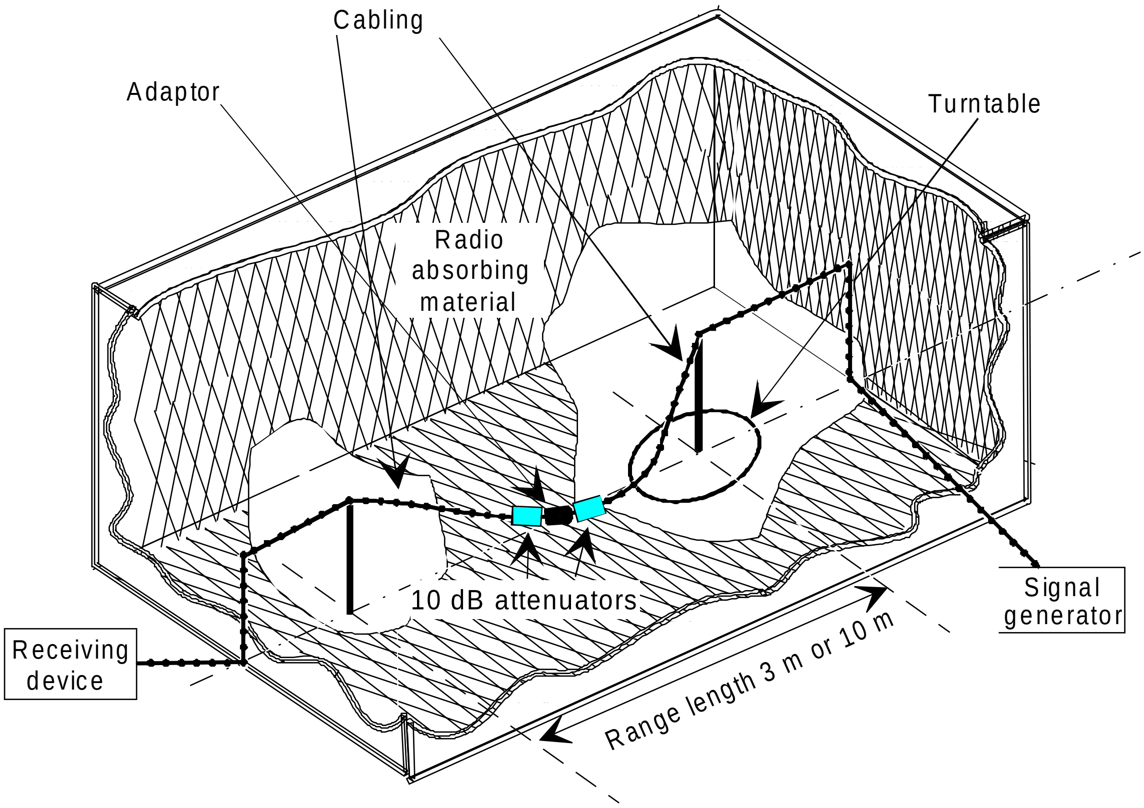

Figure 28: Anechoic chamber set-up for daily system checking

At the start of each day, system checks should be made on the equipment used in the anechoic chamber. The following checking procedures, as a minimum requirement, should be carried out.

1) All items of test equipment requiring electrical supplies should be connected to their power sources, switched on and allowed adequate time to stabilize, as recommended by the manufacturers. Where a stabilization period is not given by the manufacturer, 30 minutes should be allowed. After this time period those items of test equipment which possess the facility should have their self test/self calibration procedures performed.

2) A signal generator should be connected to the existing cabling at the turntable end. The other end of this cable should be connected via a calibrated coaxial cable/10 dB attenuator/adapter/10 dB attenuator/calibrated coaxial cable combination to existing cabling at the other end of the chamber. This existing cable should be connected to a receiving device (see figure 28). Where the use of a cable is impractical due to the arrangements within the chamber, bicones or other suitable antennas could be connected at both ends as appropriate. The signal generator should be scanned across the appropriate frequency range and the response of the receiving device noted. It should be compared with previous tests carried out under similar conditions. Any anomalies should be investigated.

7.1.2 Preparation of the EUT

The manufacturer should supply information about the EUT covering the operating frequency, polarization, supply voltage(s) and the reference face. Additional information, specific to the type of EUT should include, where relevant, carrier power, channel spacing, whether different operating modes are available (e.g. high and low power modes) and if operation is continuous or is subject to a maximum test duty cycle (e.g. one minute on, four minutes off).

Where necessary, a mounting bracket of minimal size should be available for mounting the EUT on the turntable. This bracket should be made from low conductivity, low relative dielectric constant (i.e. less than 1,5) material(s) such as expanded polystyrene, balsawood, etc.

The presence of the cables supplying power can affect the measured performance of the EUT. For this reason, attempts should be made to make them "transparent" as far as the testing is concerned. This can be achieved by routeing them by the shortest possible paths down to, and out from, the chamber screen. Additionally, where possible, these leads should be twisted together and loaded with ferrite beads at 0,15 m spacing.

7.1.3 Standard antennas

In the frequency band 30 MHz to 1 000 MHz, except where stipulated, both test and substitution/measuring antennas should be tuned half-wavelength dipoles (constructed as detailed in ANSI C63.5 [1]) aligned for the same polarization.

NOTE: Due to size constraints a shortened dipole is used over part of this frequency band. For uniformity of procedures across open area test sites and both types of anechoic chamber, a shortened dipole is used from 30 MHz up to 80 MHz. At all these frequencies the 80 MHz arm length (0,889 m) is used attached to the 20 MHz to 65 MHz balun for all test frequencies from 30 MHz to 65 MHz inclusive or to the 65 MHz to 180 MHz balun for 65 MHz to 80 MHz. Tuned half wavelength dipoles, attached to their matching baluns are used for all frequencies in the band 80 MHz to 1 000 MHz inclusive. Table 17 details dipole arm lengths (as measured from the centre of the balun block) and balun type against frequency. Where the test frequency does not correspond to a set frequency in the table the arm length to be used should be determined by linear interpolation between the closest set values.

Table 17: Dipole arm length and balun type against frequency

Frequency (MHz)	Dipole arm length (m)	Balun type	Frequency (MHz)	Dipole arm length (m)	Balun type
30	0,889	20 MHz to 65 MHz	**160**	0,440	65 MHz to 180 MHz
35	0,889		**180**	0,391	
40	0,889		**200**	0,352	180 MHz to 400 MHz
45	0,889		**250**	0,283	
50	0,889		**300**	0,235	
60	0,889		**400**	0,175	
70	0,889	65 MHz to 180 MHz	**500**	0,143	400 MHz to 1 000 MHz
80	0,889		**600**	0,117	
90	0,791		**700**	0,102	
100	0,714		**800**	0,089	
120	0,593		**900**	0,079	
140	0,508		**1 000**	0,076	

7.1.4 Mutual coupling and mismatch loss correction factors

Correction factors are included where relevant, to allow for mutual coupling and mismatch loss for the 30 MHz to 180 MHz band, based on using the recommended ANSI C63.5 [1] dipoles. These have been calculated by computer modelling of their baluns, sectional arms and the range length using MiniNEC. The factors are only valid for this particular type of dipole. However, if this type is unavailable, an alternative could be used. This alternative should be a tuned half wavelength dipole at the particular test frequency. Since correction factors have not been calculated in this document for any type other than the ANSI C63.5 [1] dipoles this will result in a greater expanded uncertainty for the measurement unless the test house/manufacturer has performed equivalent modelling on the dipoles used.

7.1.5 Power supplies to the EUT

All tests should be performed using power supplies wherever possible, including tests on EUTs 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 EUT, possibly by putting tape over its contacts. All leads involved should be taken down to the floor of the facility by the shortest possible routes, twisting pairs together and loading with ferrite beads at 0,15 m spacing.

7.1.6 Restrictions

The restriction that no part of an antenna should come within 1 m of any part of the absorbing panels should be applied at all times throughout these test methods.

7.2 Transmitter tests

7.2.1 Frequency error (30 MHz to 1 000 MHz)

Definition

The frequency error of a transmitter is the difference between the measured carrier frequency in the absence of modulation and the nominal frequency of the transmitter as stated by the manufacturer.

7.2.1.1 Apparatus required

- digital voltmeter;
- ferrite beads;
- 10 dB attenuators;
- power supply;
- connecting cables;
- anechoic chamber;
- test antenna (a half wavelength dipole, bicone or LPDA);
- frequency counter.

The type and serial numbers of all items of test equipment should be recorded in the log book results sheet (table 18).

NOTE: The half wavelength dipole antennas, incorporating matching/transforming baluns, for the procedure are available in the following bands: 20 MHz to 65 MHz, 65 to 180 MHz, 180 MHz to 400 MHz, 400 MHz to 1 000 MHz. Constructional details are contained in ANSI C63.5 [1]. In the recommended antenna scheme for this band, a shortened dipole is used at all frequencies from 30 MHz up to 80 MHz.

7.2.1.2 Method of measurement

1) The measurement should always be performed in the absence of modulation.

2) The EUT should be mounted on the turntable, whose surface is at the height specified in the relevant Standard or, where not stated, at a convenient height within the "quiet zone" of the anechoic chamber. The EUT should be mounted in an orientation which matches that of its normal usage as stated by the manufacturer. This orientation and mounting configuration should be recorded on page 1 of the log book results sheet (table 18).

   NOTE 1: The turntable should be constructed from non-conducting, low relative dielectric constant (preferably less than 1,5) material(s).

3) The test antenna (dipole, bicone or LPDA) should be oriented for the stated polarization of the EUT. For cases in which the test antenna is a tuned half wavelength dipole, this should be tuned to the nominal frequency. The output of the test antenna should be connected to the frequency counter via a 10 dB attenuator and the calibrated, ferrited coaxial cable associated with that end of the chamber (see figure 29). The phase centre of the test antenna should be at the same height above the floor as the mid point of the EUT.

   NOTE 2: Where a dipole is used, frequencies below 80 MHz require a shortened version (as defined in subclause 7.1.3) to be used. For any frequency, the dipole arm length (given in table 17) is defined from the centre of the balun block to the tip of the arm. From a fully extended state, each telescopic element, in turn, should be "pushed in" from the tip until the required length is obtained. The outermost section needs to fully compress before any of the others, and so on. Table 17 also gives the choice of balun for set frequencies. Where the test frequency does not correspond to a set frequency in the table, the arm length to be used should be determined by linear interpolation between the closest set values.

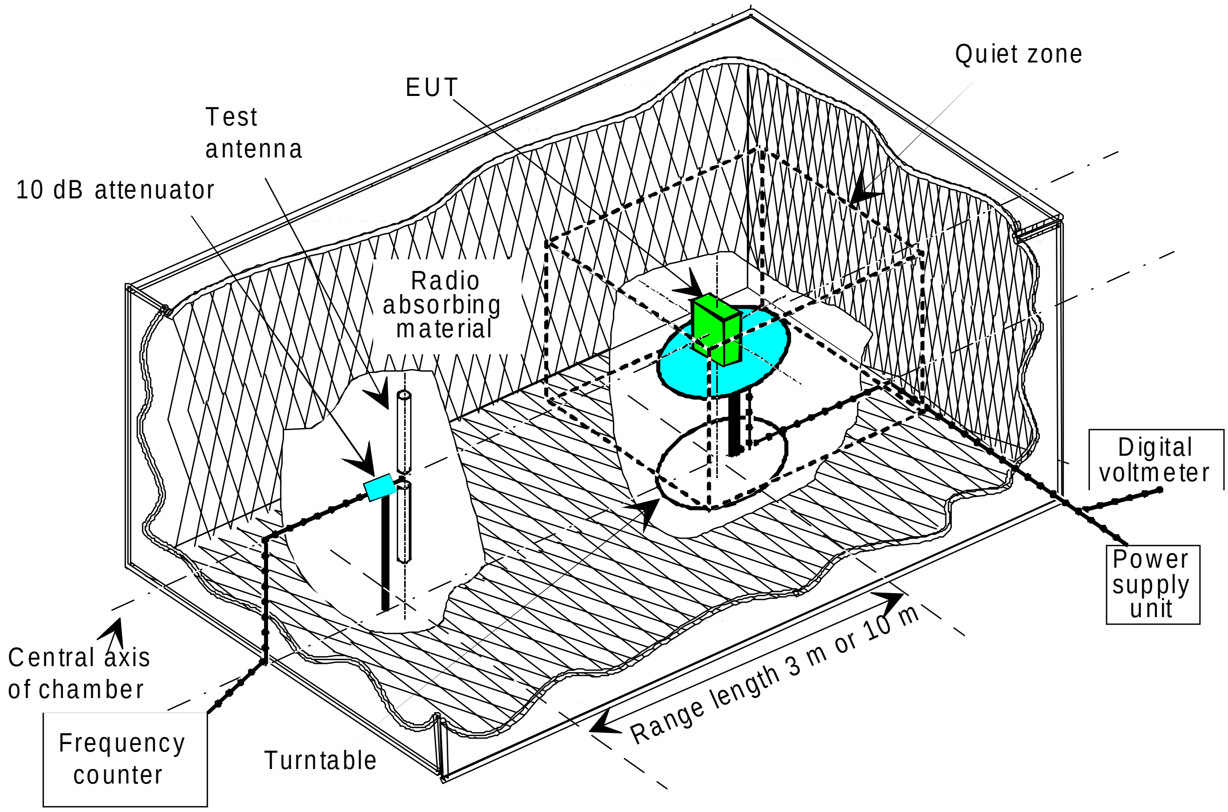

Figure 29: Anechoic chamber set-up for the Frequency error test

4) The EUT should be switched on without modulation, allowed adequate time to stabilize and the resolution of the frequency counter adjusted to read to the nearest Hz.

5) The value of the frequency displayed on the counter should be recorded in the log book results sheet (table 18).

NOTE 3: In cases where the frequency does not appear stable, this might require observations over a 30 second or 1 minute time period, noting the highest and lowest readings and estimating the average value. In these cases it is the average value that should be recorded in the log book results sheet (table 18).

7.2.1.3 Procedure for completion of the results sheets

There are two values that need to be derived before the overall results sheet (table 19) can be completed. Firstly the value for frequency error (from a straightforward calculation of recorded frequency minus the nominal frequency) and secondly, the value of the expanded uncertainty for the test. This should be carried out as given in subclause 7.2.2 and the resulting value entered in the overall results sheet (table 19).

7.2.1.4 Log book entries

Table 18: Log book results sheet

<table>
<tr><td colspan="3">FREQUENCY ERROR</td><td colspan="2">Date:</td><td>PAGE 1 of 1</td></tr>
<tr><td colspan="2">Temperature:.........°C
Manufacturer of EUT:.....................</td><td colspan="2">Humidity:...............%
Type No:.............</td><td colspan="2">Frequency:.............MHz
Serial No:..................</td></tr>
<tr><td colspan="6">Range length :.......................</td></tr>
<tr><td>Test equipment item</td><td>Type No.</td><td>Serial No.</td><td>VSWR</td><td>Insertion loss</td><td>Antenna factor/gain</td></tr>
<tr><td>Test antenna</td><td></td><td></td><td></td><td>N/A</td><td></td></tr>
<tr><td>Test antenna attenuator</td><td></td><td></td><td></td><td></td><td>N/A</td></tr>
<tr><td>Test antenna cable</td><td></td><td></td><td></td><td></td><td>N/A</td></tr>
<tr><td>Digital voltmeter</td><td></td><td></td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Power supply</td><td></td><td></td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Ferrite beads</td><td></td><td></td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Frequency counter</td><td></td><td></td><td></td><td>N/A</td><td>N/A</td></tr>
<tr><td colspan="6">Mounting configuration of EUT</td></tr>
<tr><td colspan="3">Reading on frequency counter:</td><td colspan="3">Hz</td></tr>
</table>

7.2.1.5 Statement of results

The results should be presented in tabular form as shown in table 19.

Table 19: Overall results sheet

FREQUENCY ERROR	**Date:** **PAGE 1 of 1**
Frequency error	Hz
Expanded uncertainty (95 %)	Hz

7.2.2 Expanded uncertainty for frequency error test

The method of calculating the expanded uncertainty for tests in which signal levels in dB are involved is equally adopted for the frequency error test in which all the uncertainties are in the units of Hz. That is, all the uncertainty contributions are converted into standard uncertainties and combined by the RSS method under the assumption that they are all stochastic. All the uncertainty components which contribute to the test are listed in table 20. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 20: Contributions from the measurement

uj or i	Description of uncertainty contributions	Hz
u_{i01}	*random uncertainty*	
u_{j56}	*frequency counter: absolute reading*	
u_{j05}	*mutual coupling: detuning effect of the absorbing material on the EUT*	
u_{j09}	*mutual coupling: detuning effect of the test antenna on the EUT*	

The standard uncertainties from table 20 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. The combined standard uncertainty of the frequency measurement ($u_{c\ contributions\ from\ the\ measurement}$) is the combination of the components outlined above.

$$u_c = u_{c\ contributions\ from\ the\ measurement} = \_\_,\_\_ \text{ Hz}$$

The expanded uncertainty is ± 1,96 x u_c = ± __,__ Hz at a 95 % confidence level.

7.2.3 Effective radiated power (30 MHz to 1 000 MHz)

Definition

The effective radiated power is the power radiated in the direction of the maximum field strength under specified conditions of measurement, in the absence of modulation.

7.2.3.1 Apparatus required

- digital voltmeter;
- ferrite beads;
- 10 dB attenuators;
- power supply;
- connecting cables;
- anechoic chamber;
- test antenna (half wavelength dipole as detailed in ANSI C63.5 [1] recommended);
- substitution antenna (half wavelength dipole as detailed in ANSI C63.5 [1] recommended);
- receiving device (measuring receiver or spectrum analyser);
- signal generator.

The type and serial numbers of all items of test equipment should be recorded on page 1 of the log book results sheet (table 22).

NOTE: The half wavelength dipole antennas, incorporating matching/transforming baluns, for the procedure are available in the following bands: 20 MHz to 65 MHz, 65 MHz to 180 MHz, 180 MHz to 400 MHz, 400 MHz to 1 000 MHz. Constructional details are contained in ANSI C63.5 [1]. In the recommended antenna scheme for this band, a shortened dipole is used at all frequencies from 30 MHz up to 80 MHz.

7.2.3.2 Method of measurement

1) The measurement should always be performed in the absence of modulation.

2) The EUT should be mounted directly onto the turntable, whose surface is at the height specified in the relevant standard or, where not stated, at a convenient height within the "quiet zone" of the anechoic chamber. The EUT should be mounted in an orientation which matches that of its normal usage as stated by the manufacturer. The normal to the reference face of the EUT should point directly down the chamber towards the test antenna support. This is the 0° reference angle for the test. This orientation and mounting configuration should be recorded on page 1 of the log book results sheet (table 22). The items of test equipment should be set-up as shown in figure 30.

   NOTE 1: The turntable should be constructed from non-conducting, low relative dielectric constant (preferably less than 1,5) material(s).

3) In cases where the position of the phase centre of the EUT's antenna is known, the EUT should be positioned on the turntable such that this phase centre is as coincident with the axis of rotation of the turntable as possible and either on the central axis of the chamber or at a convenient height within the quiet zone. Alternatively, if the position of the phase centre is unknown, but the antenna is a single rod which is visible and vertical in normal usage, the axis of the antenna should lie on the axis of rotation whilst its base should be positioned on the chamber's central axis (or at a convenient height within the quiet zone). If the phase centre of the EUT is unknown and no antenna is visible, the volume centre of the EUT should be used instead. The offset from the central axis of the chosen phase centre datum, should be entered on page 2 of the log book results sheet (table 22).

4) The test antenna (in the recommended scheme a tuned ANSI C63.5 [1] half wavelength dipole for frequencies of 80 MHz and above, a shortened dipole for frequencies from 30 MHz up to 80 MHz) should be tuned to the appropriate frequency and oriented for vertical polarization. Its output should be connected to the receiving device via a 10 dB attenuator and the calibrated, ferrited coaxial cable associated with that end of the chamber. The height of the phase centre of the test antenna should be at the same offset (if any) from the central axis of the chamber as the phase centre/antenna base/volume centre of the EUT, so that the measurement axis is parallel to the central axis.

   NOTE 2: The measurement axis is the straight line between the phase centres of transmitting and receiving devices.

   NOTE 3: For all frequencies below 80 MHz, a shortened dipole (as defined in subclause 7.1.3) should be used. The dipole arm length is defined from the centre of the balun block to the tip of the arm. From a fully extended state, each telescopic element, in turn, should be "pushed in" from the tip until the required length is obtained. The outermost section needs to fully compress before any of the others, and so on. Table 17 gives the dipole arm lengths and choice of balun for set frequencies. Where the test frequency does not correspond to a set frequency in the table, the arm length to be used should be determined by linear interpolation between the closest set values.

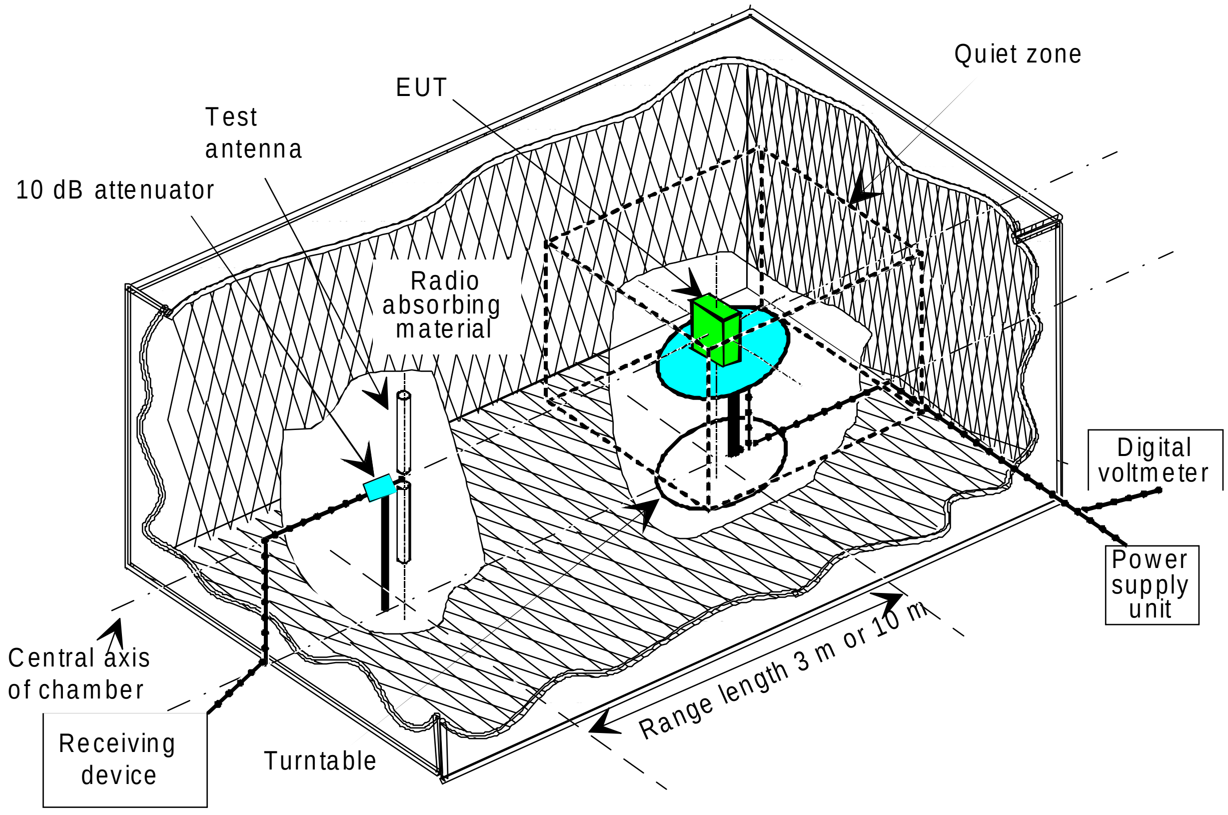

Figure 30: Anechoic chamber set-up for the effective radiated power measurement on the EUT

5) The EUT should be switched on without modulation, and the receiving device tuned to the appropriate frequency.

6) The EUT should be rotated through 360° in the horizontal plane until the maximum signal is detected on the receiving device. The angle with reference to the nominal orientation of the EUT and the maximum signal level (dBm) detected by the receiving device should be recorded on page 2 of the log book results sheet (table 22).

7) The EUT should be replaced on the turntable by the substitution antenna (identical to the test antenna), which has been adjusted to correspond to the frequency of the EUT (see figure 31).

8) The phase centre of the substitution antenna should lie directly over the axis of rotation of the turntable, whilst its height should be at the same offset from the central axis of the chamber as the phase centre of the test antenna, so that the measurement axis is again parallel to the central axis.

9) The substitution antenna should be oriented for vertical polarization and connected via a 10 dB attenuator to a calibrated signal generator using the calibrated, ferrited coaxial cable associated with the turntable end of the chamber.

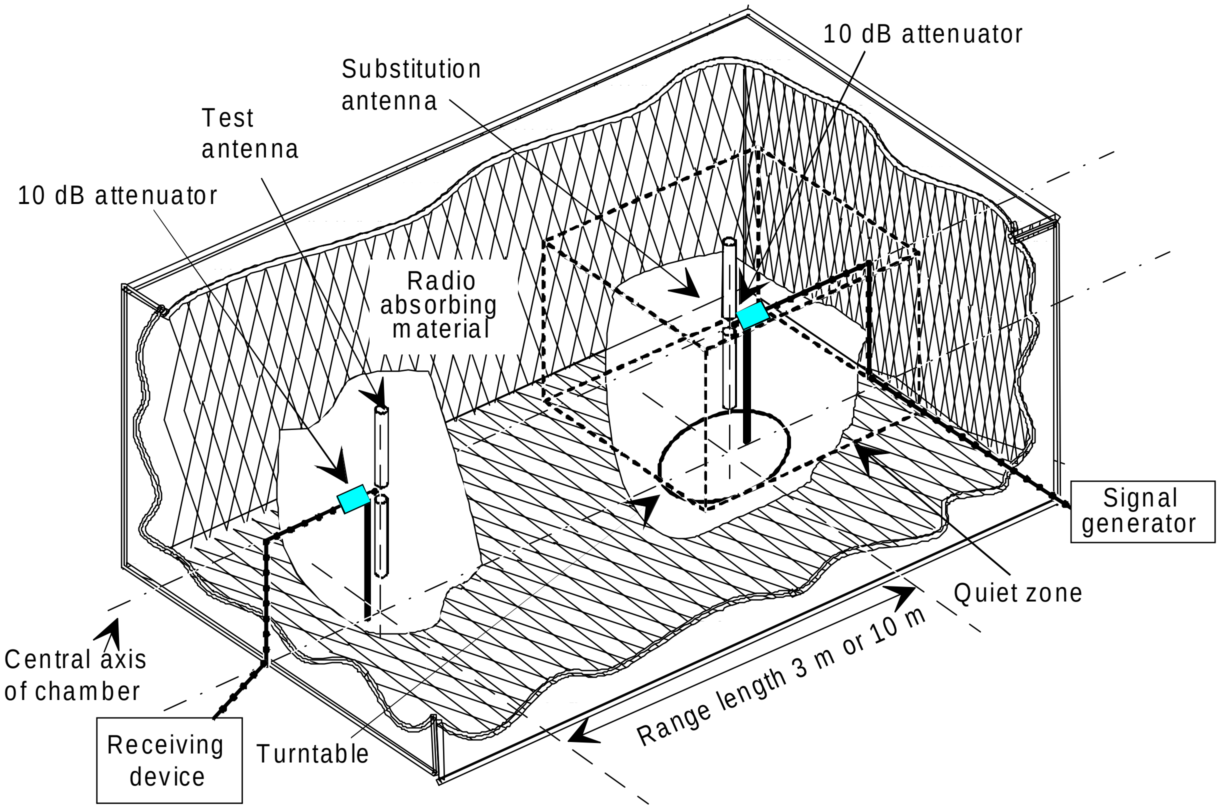

Figure 31: Substitution antenna replacing the EUT

10) The signal generator should be tuned to the appropriate frequency and its output level adjusted until the level measured on the receiving device, is at least 20 dB above the level with the output from the signal generator switched off.

11) The substitution antenna should be rotated until the maximum level is detected on the receiving device.

NOTE 4: This is to correct for possible misalignment of a directional beam i.e. dipoles used in horizontally polarized tests. This step can be omitted when dipoles are used in vertically polarized tests.

12) The output level of the signal generator should be adjusted until the level, measured on the receiving device, is identical to that recorded in step 6. This output signal level (dBm) from the signal generator should be recorded on page 2 of the log book results sheet (table 22).

NOTE 5: In the event of insufficient range of signal generator output level, the receiving device input attenuation should be decreased to compensate. The signal generator output level (dBm) and the change in attenuation (dB) should both be recorded on page 2 of the log book results sheet (table 22) in this case.

13) The EUT should be remounted on the turntable as stipulated in steps 2 and 3, the test antenna oriented for horizontal polarization and Steps 4 to 12 repeated with the substitution antenna also oriented for horizontal polarization.

7.2.3.3 Procedure for the completion of the results sheets

There are two values that need to be derived before the overall results sheet (table 23) can be completed. These are the overall measurement correction and the expanded uncertainty values.

Guidance for deriving the values of the correction factors is given in table 21.

When the correction factors have been derived, they should be entered on page 2 of the log book results sheet (table 22) as a result of which the overall correction can be calculated as follows:

overall correction = *substitution antenna cable loss*
+ *substitution antenna attenuator loss*
+ *substitution antenna balun loss*
+ *mutual coupling and mismatch loss (where applicable)*
- *gain of substitution antenna*

NOTE: For frequencies greater than 180 MHz the mutual coupling and mismatch loss factor should be taken as 0,00 dB.

The resulting value for the overall correction factor should then be entered on page 2 of the log book result sheet (table 22). The effective radiated power can then be calculated:

effective radiated power = *signal generator output level*
- *reduction in the input attenuation of receiving device (if any)*
+ *overall correction*

The only calculation that remains to be performed before the overall results sheet (table 23) can be completed is the determination of the expanded measurement uncertainty. This should be carried out as given in subclause 7.2.4 and the resulting value entered in the overall results sheet (table 23).

Table 21: Guidance for deriving correction factors

Figures for correction factors:	
Substitution antenna cable loss	Obtained directly from the calibration data
Substitution antenna attenuator loss	Obtained from calibration data
Substitution antenna balun loss	If not known from calibration data, the value should be taken as 0,30 dB
Mutual coupling and mismatch loss factors between the test antenna and substitution antenna	For ANSI dipoles (30 MHz to 180 MHz) values can be obtained from ETR 273-1-1 [8] table A.19.For frequencies greater than 180 MHz, this value is 0,00 dB. For non-ANSI dipoles this value is 0,00 dB.
Gain of substitution antenna	For ANSI dipoles (30 MHz to 1 000 MHz) the value is 2,10 dBi. For other types, the value can be obtained from calibration data

7.2.3.4 Log book entries

Table 22: Log book results sheet

EFFECTIVE RADIATED POWER		**Date:**			**PAGE 1 of 2**
Temperature:.........°C		**Humidity:...............%**		**Frequency:.............MHz**	
Manufacturer of EUT:.....................		**Type No:.............**		**Serial No:..................**	
Bandwidth of Receiving Device...................Hz					
Range length :.......................					
Test equipment item	**Type No.**	**Serial No.**	**VSWR**	**Insertion loss**	**Antenna factor/gain**
Test antenna				N/A	
Test antenna attenuator					N/A
Test antenna cable					N/A
Substitution antenna				N/A	
Substitution antenna attenuator					N/A
Substitution antenna cable					N/A
Digital voltmeter			N/A	N/A	N/A
Power supply			N/A	N/A	N/A
Receiver device				N/A	N/A
Signal generator				N/A	N/A
Ferrite beads			N/A	N/A	N/A
Mounting configuration of EUT					

(continued)

Table 22 (concluded): Log book results sheet

EFFECTIVE RADIATED POWER		Date:	PAGE 2 of 2
Vertical Polarization		**Horizontal Polarization**	
Offset of EUT's phase centre from the central axis		Offset of EUT's phase centre from the central axis	
Maximum signal level on receiving device	dBm	Maximum signal level on receiving device (dBm)	dBm
Angle at which the maximum signal is received		Angle at which the maximum signal is received	
Output level from signal generator into substitution antenna (dBm)	dBm	Output level from signal generator into substitution antenna (dBm)	dBm
Change in receiver attenuator	dB	Change in receiver attenuator	dB
Correction factors			
Substitution antenna cable loss(es)		Substitution antenna cable loss(es)	
Substitution antenna attenuator loss		Substitution antenna attenuator loss	
Substitution antenna balun loss		Substitution antenna balun loss	
Mutual coupling and mismatch loss (30 - 180 MHz)		Mutual coupling and mismatch loss (30 - 180 MHz)	
Gain of the substitution antenna		Gain of the substitution antenna	
Overall measurement correction	dB	Overall measurement correction	dB

7.2.3.5 Statement of results

The results should be presented in tabular form as shown in table 23.

Table 23: Overall results sheet

EFFECTIVE RADIATED POWER		Date:	PAGE 1 of 1
Vertical Polarization		**Horizontal Polarization**	
Effective radiated power	dBm	Effective radiated power	dBm
Expanded uncertainty (95 %)	dB	Expanded uncertainty (95 %)	dB

7.2.4 Measurement uncertainty for effective radiated power

A fully worked example illustrating the methodology to be used can be found in clause 4 of ETR 273-1-2 [9].

7.2.4.1 Uncertainty contributions: Stage 1: EUT measurement

For the measurement of effective radiated power two stages of test are involved. The first stage (the EUT measurement) is to measure on the receiving device, a level from the EUT as shown in figure 32 (shaded components are common to both stages of the test).

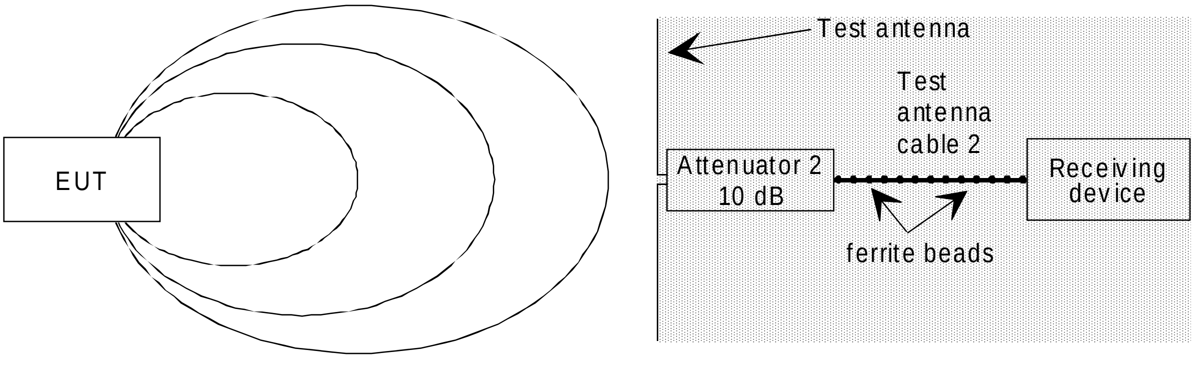

Figure 32: Stage 1: EUT measurement

Due to the commonality of all of the components from the test antenna to the receiver in both stages of the test, the mismatch uncertainty contributes identically in each stage and hence cancels. Similarly, the systematic uncertainty contributions (e.g. test antenna cable loss, etc.) of the individual components also cancel.

The magnitude of the random uncertainty contribution to each stage of the procedure can be assessed from multiple repetition of the EUT measurement. All the uncertainty components which contribute to this stage of the test are listed in table 24. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 24: Contributions from the EUT measurement

uj or i	Description of uncertainty contributions	dB
u_{j37}	*mismatch: receiving part*	
u_{j19}	*cable factor: test antenna cable*	
u_{j41}	*insertion loss: test antenna cable*	0,00
u_{j40}	*insertion loss: test antenna attenuator*	0,00
u_{j47}	*receiving device: absolute level*	
u_{j53}	*EUT: influence of setting the power supply on the ERP of the carrier*	
u_{j20}	*position of the phase centre: within the EUT volume*	
u_{j21}	*positioning of the phase centre: within the EUT over the axis of rotation of the turntable*	
u_{j50}	*EUT: influence of the ambient temperature on the ERP of the carrier*	
u_{j16}	*range length*	0,00
u_{j01}	*reflectivity of absorbing material: EUT to the test antenna*	0,00
u_{j45}	*antenna: gain of the test antenna*	0,00
u_{j46}	*antenna: tuning of the test antenna*	0,00
u_{j55}	*EUT: mutual coupling to the power leads*	
u_{j08}	*mutual coupling: amplitude effect of the test antenna on the EUT*	
u_{j04}	*mutual coupling: EUT to its images in the absorbing material*	
u_{j06}	*mutual coupling: test antenna to its images in the absorbing material*	
u_{i01}	*random uncertainty*	

The standard uncertainties from table 24 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ contribution\ from\ the\ EUT\ measurement}$) for the EUT measurement in dB.

7.2.4.2 Uncertainty contributions: Stage two: Substitution measurement

The second stage (the substitution) involves replacing the EUT with a substitution antenna and signal source as shown in figure 33 and adjusting the output level of the signal generator until the same level as in stage one is achieved on the receiving device.

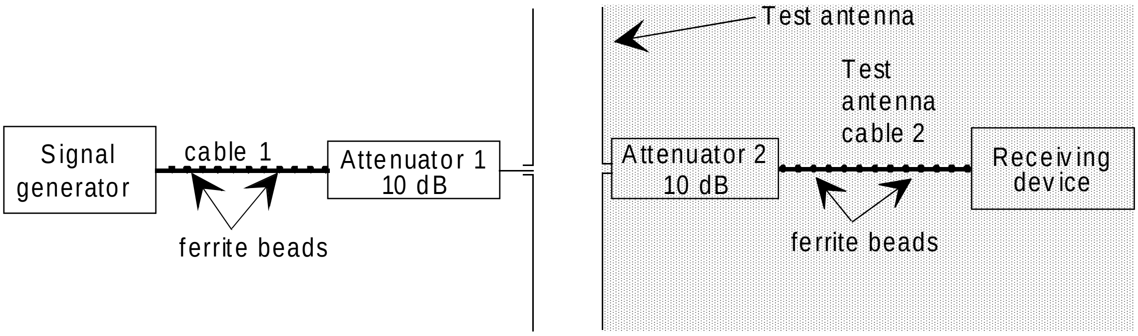

Figure 33: Stage 2: Substitution measurement

All the uncertainty components which contribute to this stage of the test are listed in table 25. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 25: Contributions from the substitution

uj or i	Description of uncertainty contributions	dB
u_{j36}	*mismatch: transmitting part*	
u_{j37}	*mismatch: receiving part*	
u_{j38}	*signal generator: absolute output level*	
u_{j39}	*signal generator: output level stability*	
u_{j19}	*cable factor: substitution antenna cable*	
u_{j19}	*cable factor: test antenna cable*	
u_{j41}	*insertion loss: substitution antenna cable*	
u_{j41}	*insertion loss: test antenna cable*	0,00
u_{j40}	*insertion loss: substitution antenna attenuator*	
u_{j40}	*insertion loss: test antenna attenuator*	0,00
u_{j47}	*receiving device: absolute level*	0,00
u_{j16}	*range length*	0,00
u_{j02}	*reflectivity of absorbing material: substitution antenna to the test antenna*	0,00
u_{j45}	*antenna: gain of the substitution antenna*	0,50
u_{j45}	*antenna: gain of the test antenna*	0,00
u_{j46}	*antenna: tuning of the test antenna*	0,00
u_{j22}	*position of the phase centre: substitution antenna*	
u_{j06}	*mutual coupling: substitution antenna to its images in the absorbing material*	
u_{j06}	*mutual coupling: test antenna to its images in the absorbing material*	0,50
u_{j11}	*mutual coupling: substitution antenna to the test antenna*	0,00
u_{j12}	*mutual coupling: interpolation of mutual coupling and mismatch loss correction factors*	0,00
u_{i01}	*random uncertainty*	

The standard uncertainties from table 25 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ contributions\ from\ the\ substitution}$) for the substitution measurement in dB.

7.2.4.3 Expanded uncertainty of the ERP measurement

The combined standard uncertainty of the effective radiated power measurement is the RSS combination of the components outlined in 7.2.4.1 and 7.2.4.2. The components to be combined are $u_{c\ contribution\ from\ the\ EUT\ measurement}$ and $u_{c\ contribution\ from\ the\ substitution}$.

$$u_c = \sqrt{u^2_{c\ contribution\ from\ the\ EUT\ measurement} + u^2_{c\ contribution\ from\ the\ substitution}} = \_\_,\_\_\ \text{dB}$$

The expanded uncertainty is ± 1,96 x u_c = ± __,__ dB at a 95 % confidence level.

7.2.5 Spurious emissions (30 MHz to 4 GHz or 12,75 GHz)

Spurious emissions are unwanted sources of radiation from an EUT. They are at frequencies other than those of the carrier and sidebands associated with normal modulation and by definition, their radiating mechanisms and locations within the equipment, as well as their directivities, polarizations and directions are unknown.

An EUT which is large in terms of wavelength, may possess highly directive (i.e. narrow beam) spurious, particularly at high frequencies, which could radiate at angles that are difficult to detect. Mainly for this reason, a "characterization" procedure, i.e. the identification of all frequencies at which an EUT radiates, should be performed in a shielded enclosure (i.e. an enclosure with metal walls but no absorbing material) prior to testing in the anechoic chamber. An additional benefit of the characterization procedure, is that it ensures that no ambient is mistaken for a spurious emission in a poorly shielded chamber. Characterization should cover the full 30 MHz to 4 GHz or 12,75 GHz band (as stated in the relevant standard).

Spurious emission testing is performed on all radio equipment possessing an integral antenna. For EUTs fitted with an external antenna connector, spurious emission testing is carried out with a broadband 50 Ω load (sometimes known as an artificial antenna) connected instead of the antenna. The test is then referred to as cabinet radiation testing.

NOTE: For integral antenna devices, the measurement of a spurious emission (for transmitters) is unavoidably performed in the presence of the carrier at full power level. Care should always be exercised under this condition to prevent overloading the input of the receiving device. For these receiving devices, for both characterization and spurious emission testing, a high "Q" notch filter (centred on the carrier frequency) should be used for frequencies up to approximately 1,5 times the carrier frequency and a high pass filter for frequencies above this (the cut-off being approximately 1,5 times the carrier frequency). This should be connected between the test antenna and the input to the receiving device as appropriate.

Definition

Spurious emissions are emissions at frequencies other than those of the carrier and sidebands associated with normal modulation.

The level of a spurious emission should be measured as either:

- the effective radiated power of the cabinet and integral antenna together, in the case of EUTs not fitted with an external antenna connector;

or

- the effective radiated power of the cabinet and structure of the equipment combined (this is termed cabinet radiation) in the case of EUTs fitted with a external antenna connector.

7.2.5.1 Apparatus required

- digital voltmeter;
- ferrite beads;
- 10 dB attenuators;
- power supply;
- connecting cables;
- anechoic chamber;
- shielded chamber (non-anechoic);
- broadband test antenna (biconic, typically 30 MHz to 200 MHz, LPDAs, typically 200 MHz to 1 GHz and 1 GHz to 12,75 GHz or waveguide horns, typically 1 GHz to 12,75 GHz);
- substitution antenna (half wavelength dipole as detailed in ANSI C63.5 [1] recommended 30 MHz to1 000 MHz and waveguide horns for 1 GHz to 12,75 GHz);
- receiving device (measuring receiver or spectrum analyser);
- signal generator;
- high "Q" notch filter and high pass filter - only for tests on equipment not fitted with a permanent antenna connector;
- 50 Ω load - only for tests on EUTs fitted with a permanent antenna connector. This load should perform well throughout the entire frequency band (typically VSWR 1,25:1 up to 1 000 MHz, better than 2,0:1 for 1 GHz to 4 GHz or 12,75 GHz). It should be able to absorb the maximum carrier power at the nominal frequency of the EUT.

The types and serial numbers of all items of test equipment should be recorded on page 1 of the log book results sheet (table 27).

NOTE: The half wavelength dipole antennas, incorporating matching/transforming baluns, for the procedure are available in the following bands: 20 MHz to 65 MHz, 65 MHz to 180 MHz, 180 MHz to 400 MHz, 400 MHz to 1 000 MHz. Constructional details are contained in ANSI C63.5 [1]. In the recommended antenna scheme for this band, a shortened dipole is used at all frequencies from 30 MHz up to 80 MHz.

7.2.5.2 Method of measurement

Characterization

The process of characterization should take place within a shielded, totally reflecting enclosure where no absorbing material is present.

C1) The EUT should be mounted on a non-conducting turntable of low relative dielectric constant (preferably less than 1,5) material(s) in a shielded enclosure. (i.e. no absorber).

C2) The test equipment should be arranged as shown in figure 34. The protecting filter should only be used for EUTs which are not fitted with an external antenna connector. For those which do have such a connector, the broadband 50 Ω load should be connected to the EUT and the filter becomes unnecessary.

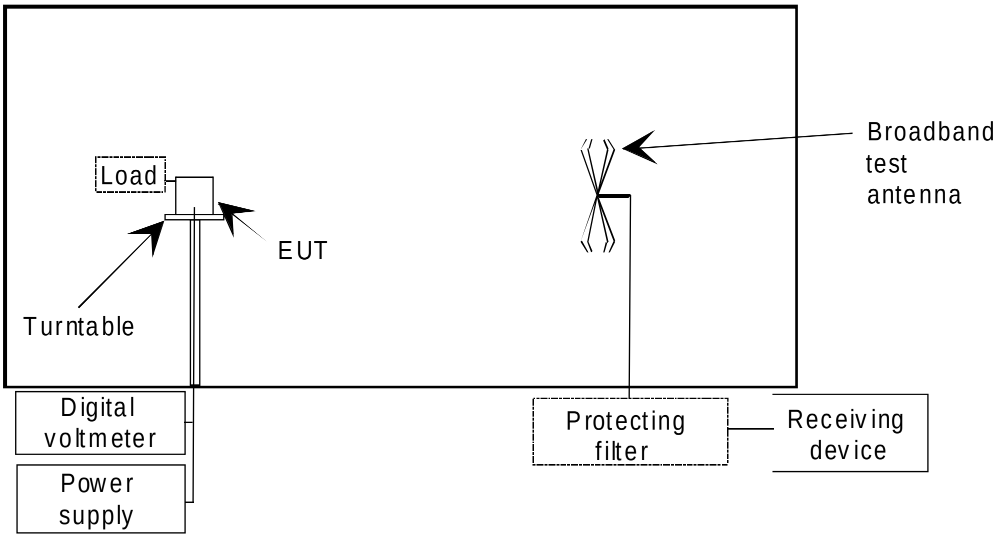

Figure 34: Elevation view of shielded chamber set up for the characterization tests

C3) The EUT should be mounted in the position closest to normal use as declared by the manufacturer. This mounting configuration should be recorded on page 1 of the log book results sheet (table 27).

C4) The broadband test antenna should be aligned for vertical polarization and spaced a convenient distance away from the EUT.

NOTE 1: For the purposes of this characterization procedure, the range length does not have to meet the conditions for far-field testing given earlier.

C5) The EUT should be switched on, without modulation, and the receiving device scanned through the appropriate frequency band, avoiding the carrier frequency and its adjacent channels. All frequencies producing a response on the receiving device should be recorded on page 2 of the log book results sheet (table 27).

NOTE 2: The test antenna should be changed as necessary to ensure that the complete frequency range is covered.

C6) The broadband test antenna should be aligned for horizontal polarization and step C5 repeated.

NOTE 3: The only information provided by the characterization procedure is which frequencies should be measured in the anechoic chamber.

Measurement

NOTE 4: The following procedure steps involve, for every frequency identified in the characterization procedure, scanning for the peak of the spurious emission in both horizontal and vertical planes around the EUT. The amplitude peak in both planes is measured in both horizontal and vertical polarizations. Large EUTs, however, may possess highly directional spurious emissions particularly at high frequencies and, despite the two plane scanning, there remains for these cases, a small probability that no spurious can be detected.

1) The measurement should always be performed in the absence of modulation.

2) The EUT should be mounted directly onto the turntable, whose surface is at the height specified in the relevant standard or, where not stated, at a convenient height within the "quiet zone" of the anechoic chamber. The EUT should be mounted in an orientation which matches that of its normal usage as stated by the manufacturer. The normal to the reference face of the EUT should point directly down the chamber towards the test antenna support. This is the 0° reference angle for the test. This orientation and mounting configuration should be recorded on page 1 of the log book results sheet (table 27). The items of test equipment should be set-up as shown in figure 35.

NOTE 5: The turntable should be constructed from non-conducting, low relative dielectric constant (preferably less than 1,5) material(s).

3) The EUT should be positioned such that its volume centre lies on the axis of rotation of the turntable and either on the central axis of the chamber or at a convenient height within the quiet zone (see figure 35). The offset from the central axis of the volume centre should be entered on page 2 of the log book results sheet (table 27).

4) For EUTs fitted with an external antenna connector, the broadband 50 Ω load should be connected in place of the antenna.

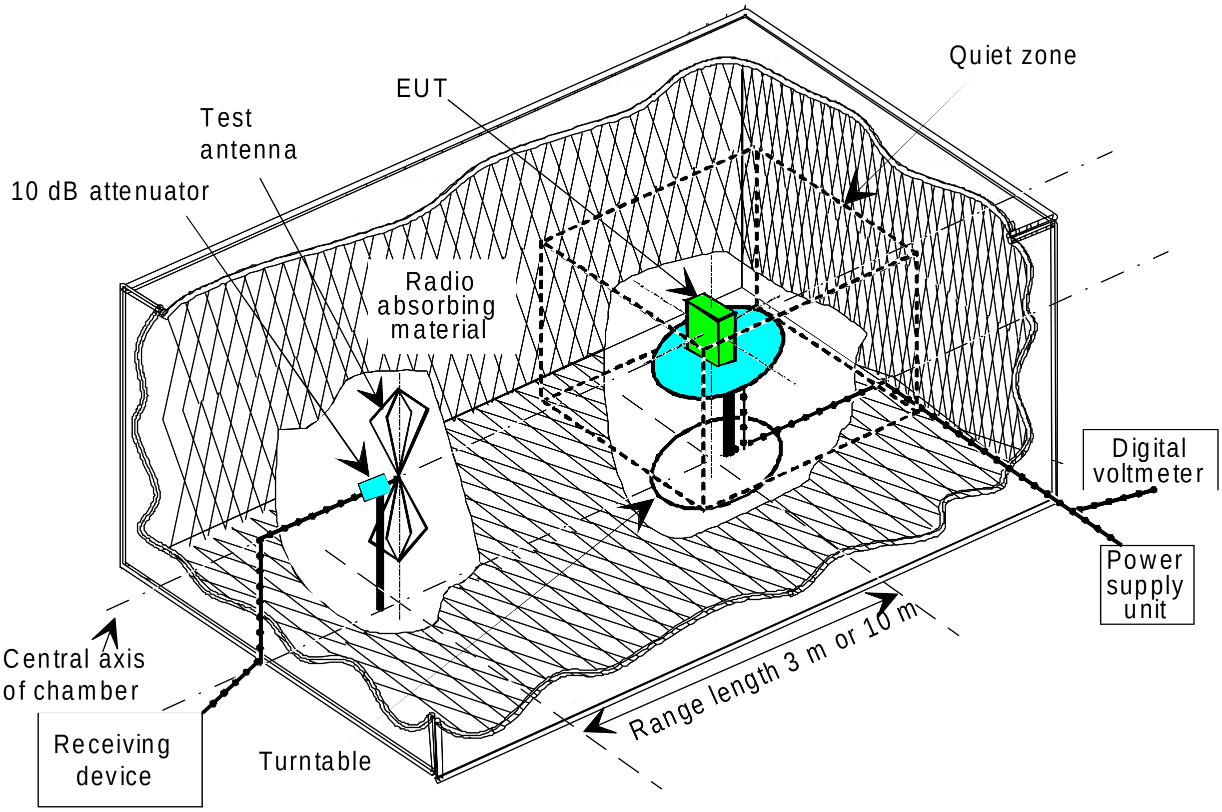

Figure 35: Anechoic chamber set up for Spurious emissions testing on the EUT

5) The test antenna (biconic, LPDA or waveguide horn) should be oriented for vertical polarization. Its output should be connected to the receiving device via a 10 dB attenuator and the calibrated, ferrited coaxial cable associated with that end of the chamber, and a protective filter (only if the EUT does not possess an external antenna connector). The height of the phase centre of the test antenna should be at the same offset (as recorded in Step 3) from the central axis of the chamber as the volume centre of the EUT, so that the measurement axis is parallel to the central axis.

NOTE 6: The measurement axis is the straight line between the phase centres of transmitting and receiving devices.

6) The EUT should be switched on, without modulation, and the receiving device tuned to the first frequency recorded on page 2 of the log book results sheet (table 27).

7) The EUT should be rotated through 360° in the azimuth plane until the maximum signal level is observed on the receiving device. The corresponding received level (dBm_1) and the angle of the turntable ($angle_1$) should be recorded on page 2 of the log book results sheet (table 27).

8) The polarization of the test antenna should be changed to horizontal and the received signal level (dBm_2) again recorded on page 2 of the log book results sheet (table 27). If this value of signal level is more than 20 dB below that measured in Step 7, the peak of this spurious, to be entered on page 2 of the log book results sheet (table 27) as "Spurious level 1", is simply the level measured in Step 7. Equally, if dBm_2 exceeds dBm_1 by more than 20 dB, "Spurious level 1" is simply dBm_2. Alternatively, the spurious level should be calculated as:

$$\textit{Spurious level } 1 = 20\log\left(10^{\left(\frac{dBm_1}{20}\right)} + 10^{\left(\frac{dBm_2}{20}\right)}\right)\text{dBm}$$

The resulting value should be entered in the log book results sheet as "Spurious level 1".

9) Retaining the test antenna polarization (horizontal), the EUT should be rotated about its volume centre to lie on its side as shown in figure 36. The EUT should again be rotated through 360° in the azimuth plane until the maximum signal level is observed on the receiving device. The corresponding received level (dBm_3) and the angle of the turntable ($angle_2$) should be recorded on page 2 of the log book results sheet (table 27).

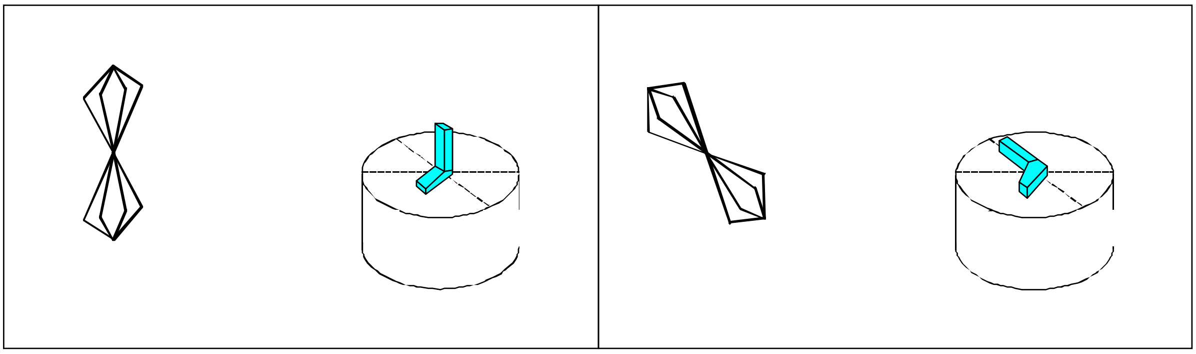

Figure 36: Turning the EUT

10) The polarization of the test antenna should be changed to vertical and the received signal level (dBm_4) again recorded on page 2 of the log book results sheet (table 27). If this value of signal level is more than 20 dB below that measured in Step 9, the peak of this spurious, to be entered on page 2 of the log book results sheet (table 27) as "Spurious level 2", is simply the level measured in Step 9. Equally, if dBm_4 exceeds dBm_3 by more than 20 dB, "Spurious level 2" is simply dBm_4. Alternatively, the spurious level should be calculated as:

$$\textit{Spurious level } 2 = 20\log\left(10^{\left(\frac{dBm_3}{20}\right)} + 10^{\left(\frac{dBm_4}{20}\right)}\right)\text{dBm}$$

The resulting value should be entered in the log book results sheet as "Spurious level 2".

Whichever value is the larger of "Spurious level 1" and "Spurious level 2", it should be entered as "Overall spurious level" on page 2 of the log book results sheet (table 27).

11) The EUT should be replaced on the turntable by the substitution antenna (a tuned half wavelength dipole which has been adjusted to correspond to the appropriate frequency or waveguide horn) (see figure 37).

NOTE 7: For all frequencies below 80 MHz, a shortened dipole (as defined in subclause 7.1.3) should be used. The dipole arm length is defined from the centre of the balun block to the tip of the arm. From a fully extended state, each telescopic element, in turn, should be "pushed in" from the tip until the required length is obtained. The outermost section needs to fully compress before any of the others, and so on. table 17 gives the dipole arm lengths and choice of balun for set frequencies. Where the test frequency does not correspond to a set frequency in the table, the arm length to be used should be determined by linear interpolation between the closest set values.

12) The phase centre of the substitution antenna should lie directly over the axis of rotation of the turntable, whilst its height should be at the same offset (as recorded in Step 3) from the central axis of the chamber, so that the measurement axis is again parallel to the central axis.

NOTE 8: The phase centre of a dipole is in the centre of its two rods and for a waveguide horn it is in the centre of its open mouth.

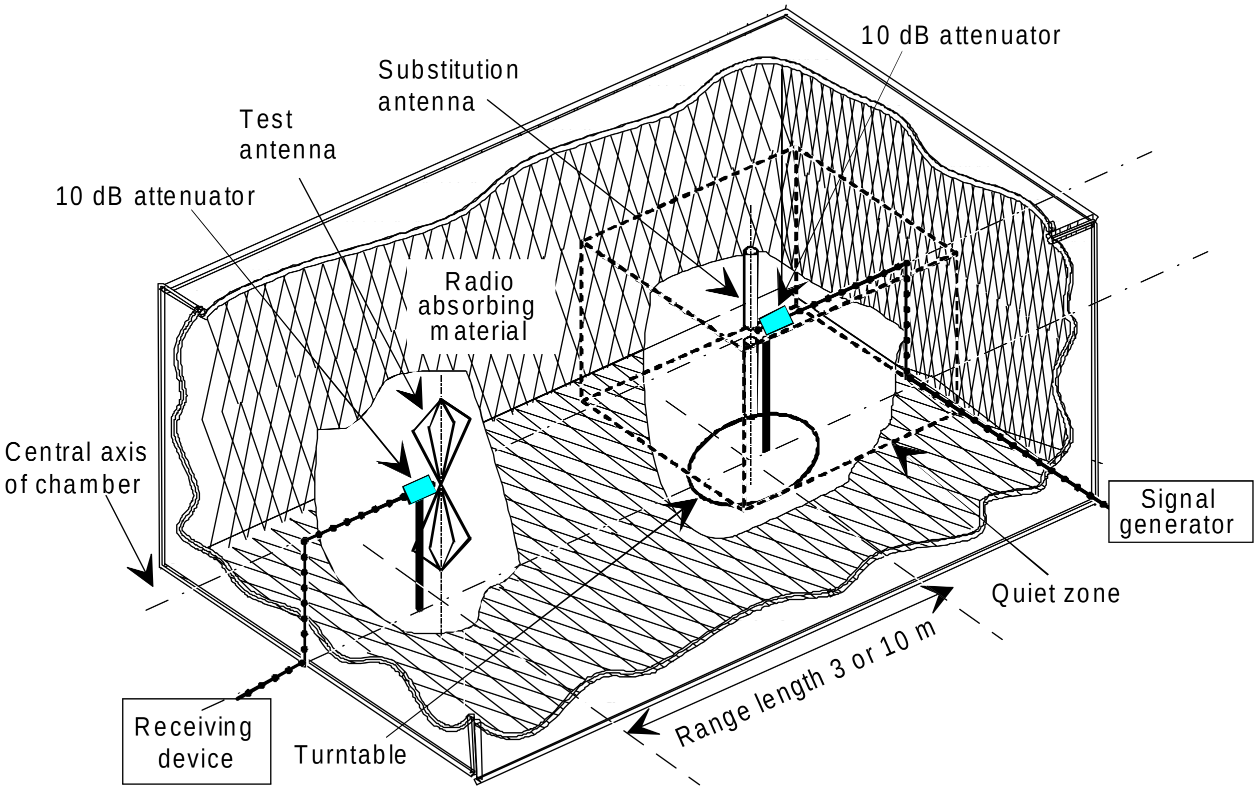

Figure 37: Substitution antenna replacing the EUT for spurious emission testing in an anechoic chamber

13) The substitution antenna should be oriented for vertical polarization and connected to a calibrated signal generator via a 10 dB attenuator and the calibrated, ferrited coaxial cable associated with that end of the chamber.

14) The signal generator should be tuned to the appropriate frequency and its output level adjusted until the level measured on the receiving device, is at least 20 dB above the level with the output from the signal generator switched off.

15) The substitution antenna should be rotated until the maximum level is detected on the receiving device.

NOTE 9: This is to correct for possible misalignment of a directional beam (i.e. as produced by waveguide horns in all tests and by dipoles when used in horizontally polarized tests only). This step can be omitted for dipoles used in vertically polarized tests.

16) The output level of the signal generator should be adjusted until the level, measured on the receiving device, is identical to the "Overall spurious level" recorded in Step 10. This output signal level should be recorded (dBm_5) on page 2 of the log book results sheet (table 27).

NOTE 10: In the event of insufficient range of signal generator output level, the input attenuation to the receiving device should be decreased to compensate. The signal generator output level (dBm_6) and the change in attenuation (dB, where a decrease is taken as + dB, an increase is taken as - dB) should be recorded on page 2 of the log book results sheet (table 27).

17 Steps 2 to 16 should be repeated for all the other frequencies recorded in the log book results sheet (table 27), changing the antennas as necessary.

7.2.5.3 Procedure for completion of the results sheets

There are several values that remain to be entered in the overall results sheet (table 28). These are the overall spurious emission levels (corrected for the systematic offsets involved in the measurement) and the expanded measurement uncertainty.

Guidance for deriving the values of the correction factors is given in table 26.

When the correction factors have been derived, they should be entered on page 2 of the log book results sheet (table 27). The overall correction for each spurious frequency can be calculated as follows:

overall correction = *substitution antenna cable loss*
+ substitution antenna attenuator loss
+ substitution antenna balun loss
+ mutual coupling and mismatch loss (where applicable)
- gain of substitution antenna

NOTE: For frequencies greater than 180 MHz the mutual coupling and mismatch loss factor should be taken as 0,00 dB.

The resulting values should be entered on page 2 of the results sheet (table 27) and the effective radiated power of each spurious emission calculated from:

spurious ERP = *signal generator output level*
- reduction in the input attenuation of receiving device (if any)
+ overall correction

Each value of spurious emission effective radiated power should be entered on page 2 of the log book results sheet (table 27) and in the overall results sheet (table 28).

The final value to be entered in the overall results sheet (table 28) is that for the expanded uncertainty. This should be calculated according to subclause 7.2.6.

Table 26: Guidance for deriving correction factors

Figures for correction factors:	
Substitution antenna cable loss	Obtained directly from the calibration data
Substitution antenna attenuator loss	Obtained from calibration data
Substitution antenna balun loss	For dipoles: if not known from calibration data, the value should be taken as 0,30 dB. For waveguide horns: taken as 0,00 dB
Mutual coupling and mismatch loss factors between the test antenna and substitution antenna	For ANSI dipoles (30 MHz to 180 MHz) values can be obtained from ETR 273-1-1 [8] table A.19. For frequencies greater than 180 MHz, this value is 0,00 dB. For non-ANSI dipoles and waveguide horns this value is 0,00 dB
Gain of substitution antenna	For ANSI dipoles (30 MHz to 1 000 MHz) the value is 2,10 dBi. For other types of antennas (non-ANSI dipoles or waveguide horns), the value can be obtained from calibration data

7.2.5.4 Log book entries

Table 27: Log book results sheet

SPURIOUS EMISSIONS			**Date:**		**PAGE 1 of 2**
Temperature:………°C		**Humidity:…............%**		**Frequency:…..........MHz**	
Manufacturer of EUT:…..................		**Type No:…...........**		**Serial No:…...............**	
Bandwidth of Receiving Device…...............Hz					
Range length :…....................					
Test equipment item	**Type No.**	**Serial No.**	**VSWR**	**Insertion loss**	**Antenna factor/gain**
Broadband test antenna (typically 30 to 200 MHz)				N/A	
Broadband test antenna (typically 200 MHz to 1 GHz)				N/A	
Broadband test antenna (typically 1 to 12,75 GHz)				N/A	
Test antenna attenuator					N/A
Test antenna cable					N/A
Substitution antenna (typically ANSI C63.5 [1] 30 to 1 000 MHz)				N/A	
Substitution antenna (typically waveguide horns 1 to 12,75 GHz)				N/A	
Substitution antenna attenuator					N/A
Substitution antenna cable					N/A
Digital voltmeter			N/A	N/A	N/A
Power supply			N/A	N/A	N/A
Receiving device				N/A	N/A
Signal generator				N/A	N/A
Ferrite beads			N/A	N/A	N/A
High "Q" notch filter					N/A
High pass filter					N/A
Mounting configuration of EUT (Characterization)					
Mounting configuration of EUT (Measurement)					

(continued)

Table 27 (concluded): Log book results sheet

SPURIOUS EMISSIONS	Date:					PAGE 2 of 2
Offset of volume centre of the EUT from the central axis of the chamber:……………..m							
Frequency (MHz)							
dBm_1							
$angle_1$							
dBm_2							
Spurious level 1 (dBm)							
dBm_3							
$angle_2$							
dBm_4							
Spurious level 2 (dBm)							
Overall spurious level (dBm)							
Signal generator output level dBm_5 (dBm)							
Change in attenuator level (dB)							
Spurious emission ERP (dBm)							
Correction factors							
Frequency (MHz)							
Substitution antenna cable loss							
Substitution antenna attenuator loss							
Substitution antenna balun loss							
Mutual coupling and mismatch loss (30 - 180 MHz)							
Gain of the substitution antenna							
Overall measurement correction	dB	dB	dB	dB	dB	dB	dB

7.2.5.5 Statement of results

The results should be presented in tabular form as shown in table 28.

Table 28: Overall results sheet

SPURIOUS EMISSIONS	Date:					PAGE 1 of 1
Frequency (MHz)							
Spurious emission ERP (dBm)							
Expanded uncertainty (95 %)	dB	dB	dB	dB	dB	dB	dB

7.2.6 Measurement uncertainty for Spurious emissions

A fully worked example illustrating the methodology to be used can be found in clause 4 of ETR 273-1-2 [9].

7.2.6.1 Uncertainty contributions: Stage 1: EUT measurement

For the measurement of spurious effective radiated power two stages of test are involved. The first stage (the EUT measurement) is to measure on the receiving device, a level from the EUT as shown in figure 38 (shaded components are common to both stages of the test).

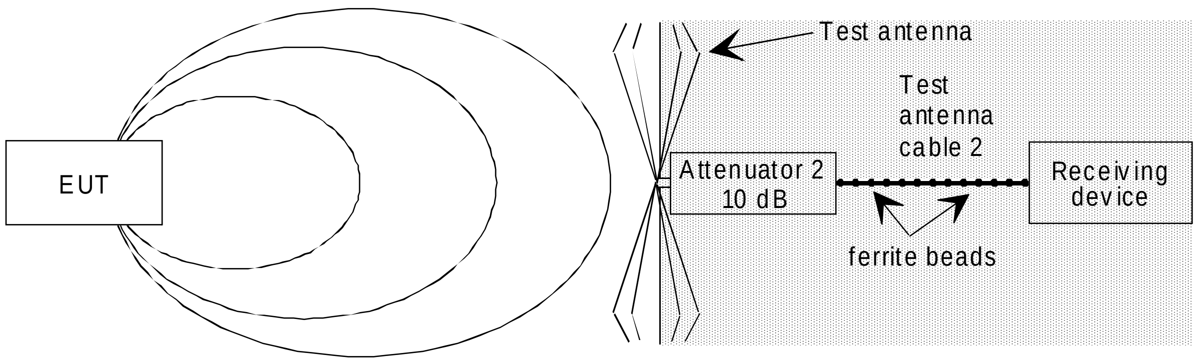

Figure 38: Stage 1: EUT measurement

Due to the commonality of all of the components from the test antenna to the receiver in both stages of the test, the mismatch uncertainty contributes identically in each stage and hence cancels. Similarly, the systematic uncertainty contributions (e.g. test antenna cable loss, etc.) of the individual components also cancel.

The magnitude of the random uncertainty contribution to this stage of the procedure can be assessed from multiple repetition of the EUT measurement.

All the uncertainty components which contribute to this stage of the test are listed in table 29. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 29: Contributions from the EUT measurement

uj or i	Description of uncertainty contributions	dB
u_{j37}	*mismatch: receiving part*	0,00
u_{j40}	*insertion loss: test antenna attenuator*	0,00
u_{j41}	*insertion loss: test antenna cable*	0,00
u_{j19}	*cable factor: test antenna cable*	
u_{j47}	*receiving device: absolute level*	0,00
u_{j54}	*EUT: influence of setting the power supply on the spurious emission level*	0,03
u_{j20}	*position of the phase centre: within the EUT volume*	
u_{j21}	*positioning of the phase centre: within the EUT over the axis of rotation of the turntable*	
u_{j51}	*EUT: influence of the ambient temperature on the spurious emission level*	0,03
u_{j16}	*range length*	0,00
u_{j01}	*reflectivity of absorbing material: EUT to the test antenna*	0,00
u_{j45}	*antenna: gain of the test antenna*	0,00
u_{j46}	*antenna: tuning of the test antenna*	0,00
u_{j55}	*EUT: mutual coupling to the power leads*	
u_{j08}	*mutual coupling: amplitude effect of the test antenna on the EUT*	0,00
u_{j04}	*mutual coupling: EUT to its images in the absorbing material*	
u_{j06}	*mutual coupling: test antenna to its images in the absorbing material*	0,00
u_{i01}	*random uncertainty*	

The standard uncertainties from table 29 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ contribution\ from\ the\ EUT\ measurement}$) for the EUT measurement in dB.

7.2.6.2 Uncertainty contributions: Stage 2: Substitution measurement

The second stage (the substitution) involves replacing the EUT with a substitution antenna and signal source as shown in figure 39 and adjusting the output level of the signal generator until the same level as in stage one is achieved on the receiving device.

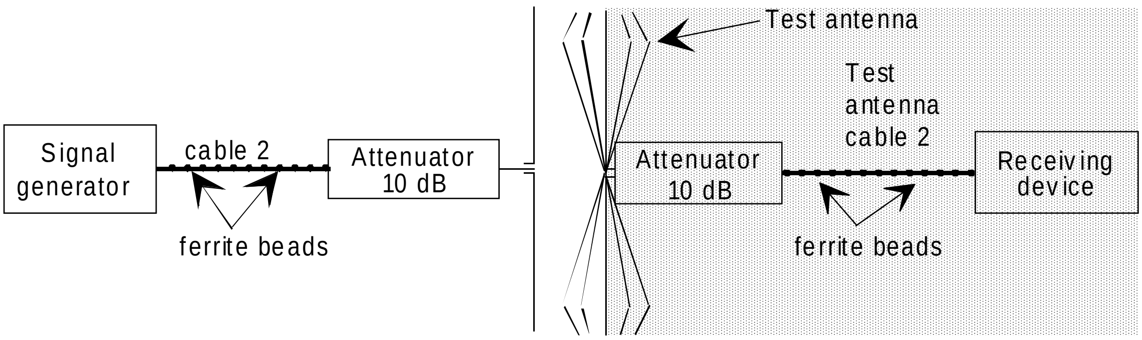

Figure 39: Stage 2: Substitution measurement

All the uncertainty components which contribute to this stage of the test are listed in table 30. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 30: Contributions from the substitution

uj or i	Description of uncertainty contributions	dB
u_{j36}	*mismatch: transmitting part*	
u_{j37}	*mismatch: receiving part*	
u_{j38}	*signal generator: absolute output level*	
u_{j39}	*signal generator: output level stability*	
u_{j19}	*cable factor: substitution antenna cable*	
u_{j19}	*cable factor: test antenna cable*	
u_{j41}	*insertion loss: substitution antenna cable*	
u_{j41}	*insertion loss: test antenna cable*	0,00
u_{j40}	*insertion loss: substitution antenna attenuator*	
u_{j40}	*insertion loss: test antenna attenuator*	0,00
u_{j47}	*receiving device: absolute level*	0,00
u_{j16}	*range length*	0,00
u_{j02}	*reflectivity of absorbing material: substitution antenna to the test antenna*	0,00
u_{j45}	*antenna: gain of the substitution antenna*	
u_{j45}	*antenna: gain of the test antenna*	0,00
u_{j46}	*antenna: tuning of the test antenna*	0,00
u_{j22}	*position of the phase centre: substitution antenna*	
u_{j06}	*mutual coupling: substitution antenna to its images in the absorbing material*	
u_{j06}	*mutual coupling: test antenna to its images in the absorbing material*	
u_{j11}	*mutual coupling: substitution antenna to the test antenna*	0,00
u_{j12}	*mutual coupling: interpolation of mutual coupling and mismatch loss correction factors*	0,00
u_{i01}	*random uncertainty*	

The standard uncertainties from table 30 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ contribution\ from\ the\ substitution}$) for the EUT measurement in dB.

7.2.6.3 Expanded uncertainty of the spurious emission

The combined standard uncertainty of the ERP measurement of the spurious emission is the combination of the components outlined in subclauses 7.2.6.1 and 7.2.6.2. The components to be combined are $u_{c\ contribution\ from\ the\ EUT\ measurement}$ and $u_{c\ contribution\ from\ the\ substitution}$.

$$u_c = \sqrt{u^2_{c\,contribution\ from\ the\ EUT\ measurement} + u^2_{c\,contribtution\ from\ the\ substitution}} = \_\_,\_\_\ \text{dB}$$

The expanded uncertainty is ± 1,96 x u_c = ± __,__ dB at a 95 % confidence level.

7.2.7 Adjacent channel power

This test is normally carried out using a test fixture and as a result has not been considered for the anechoic chamber.

7.3 Receiver tests

The tests carried out on receivers can be divided into two categories, namely sensitivity and immunity. However, only sensitivity tests are considered here.

7.3.1 Sensitivity tests (30 MHz to 1 000 MHz)

The test method for measuring the maximum or average usable sensitivity of a receiver is in two parts. In the first part, a transform factor for the chamber (i.e. the relationship in decibels between the output power level (in dBm) from the signal generator to the resulting electric field strength (in dBµV/m) at the point of test) is determined. In the second part, the sensitivity of the EUT is measured by finding the lowest output level from the signal generator which produces the required response at each of eight angles in the horizontal plane.

The receiver output depends on the type of information the receiver has been designed to demodulate. There are principally three different types of information: analogue speech, bit stream and messages.

Definitions:

For analogue speech:

- the ***maximum usable sensitivity*** expressed as field strength is the minimum of 8 field strength (in dBµV/m) measurements (at 45° increments in the horizontal plane) at the nominal frequency of the receiver and with specified test modulation, which produces a SINAD ratio of 20 dB measured at the receiver input through a telephone psophometric weighting network. The starting horizontal angle is the reference orientation as stated by the manufacturer.

- the ***average usable sensitivity*** expressed as field strength is the average of eight field strength (in dBµV/m) measurements (at 45° increments in the horizontal plane) at the nominal frequency of the receiver and with specified test modulation, which produces a SINAD ratio of 20 dB measured at the receiver input through a telephone psophometric weighting network. The starting horizontal angle is the reference orientation as stated by the manufacturer.

For bit stream:

- the ***maximum usable sensitivity*** expressed as field strength is the minimum of eight field strength (in dBµV/m) measurements (at 45° increments in the horizontal plane) at the nominal frequency of the receiver and with specified test modulation, which produces, after demodulation, a data signal with a bit error ratio of 10^{-2} measured at the receiver input. The starting horizontal angle is the reference orientation as stated by the manufacturer.

- the ***average usable sensitivity*** expressed as field strength is the average of eight field strength (in dBµV/m) measurements (at 45° increments in the horizontal plane) at the nominal frequency of the receiver and with specified test modulation, which produces, after demodulation, a data signal with a bit error ratio of 10^{-2} measured at the receiver input. The starting horizontal angle is the reference orientation as stated by the manufacturer.

For messages:

- the ***maximum usable sensitivity*** expressed as field strength is the minimum of eight field strength (in dBµV/m) measurements (at 45° increments in the horizontal plane) at the nominal frequency of the receiver, and with specified test modulation, which produces, after demodulation, a message acceptance ratio of 80 % measured at the receiver input. The starting horizontal angle is the reference orientation as stated by the manufacturer.

- the ***average usable sensitivity*** expressed as field strength is the average of eight field strength (in dBμV/m) measurements (at 45° increments in the horizontal plane) at the nominal frequency of the receiver and with specified test modulation, which produces, after demodulation, a message acceptance ratio of 80 % measured at the receiver input. The starting horizontal angle is the reference orientation as stated by the manufacturer.

7.3.1.1 Apparatus required

- digital voltmeter;
- ferrite beads;
- 10 dB attenuators;
- power supply;
- connecting cables;
- anechoic chamber;
- test antenna (half wavelength dipole as detailed in ANSI C63.5 [1] recommended);
- measuring antenna (half wavelength dipole as detailed in ANSI C63.5 [1] recommended);
- RF Signal generator;
- receiving device (measuring receiver or spectrum analyser).

Additional requirements for analogue speech:

- AF source;
- SINAD meter (incorporating telephone psophometric weighting network);
- acoustic coupler (alternatively: audio load).

Additional requirements for bit stream:

- bit stream generator;
- bit error measuring test set.

Additional requirements for messages:

- acoustic coupler;
- message generator;
- response measuring test set.

The types and serial numbers of all items of test equipment should be recorded on page 1 of the log book results sheet (table 32).

NOTE: The half wavelength dipole antennas, incorporating matching/transforming baluns, for the procedure are available in the following bands: 20 MHz to 65 MHz, 65 MHz to 180 MHz, 180 MHz to 400 MHz, 400 MHz to 1 000 MHz. Constructional details are contained in ANSI C63.5 [1]. In the recommended antenna scheme for this band, a shortened dipole is used at all frequencies from 30 MHz up to 80 MHz.

7.3.1.2 Method of measurement

Determination of the transform factor for the test site

1) For this part of the test, it is necessary to position the measuring antenna within the chamber, such that its phase centre is at the same point that the phase centre of the EUT will occupy in the second part of the test (the EUT being mounted in an orientation which matches that of its normal usage as declared by the manufacturer). The precise point should always be on the axis of rotation of the turntable, and either on the central axis of the chamber or at a convenient height within the quiet zone. The vertical offset of the phase centre of the EUT from the central axis (if any) should be either measured remotely or determined by sitting the EUT on the turntable. The vertical offset should be recorded on page 2 of the log book results sheet (table 32).

NOTE 1: If the position of the phase centre within the EUT is unknown but the antenna is visible, then the vertical offset from the central axis of the point at which the antenna meets the case of the EUT should be used. If the phase centre is unknown and there is no visible antenna the volume centre of the EUT should be used instead.

2) The measuring antenna (in the recommended scheme: a tuned ANSI C63.5 [1] half wavelength dipole for frequencies of 80 MHz and above, a shortened dipole for frequencies from 30 up to 80 MHz) should be adjusted to correspond to the nominal frequency of the EUT and positioned with its phase centre on the axis of rotation of the turntable and at the same vertical offset from the central axis of the chamber (if any) as determined for the EUT in Step 1. The measuring antenna should be oriented for vertical polarization.

NOTE 2: For all frequencies below 80 MHz, a shortened dipole (as defined in subclause 7.1.3) should be used. The dipole arm length is defined from the centre of the balun block to the tip of the arm. From a fully extended state, each telescopic element, in turn, should be "pushed in" from the tip until the required length is obtained. The outermost section needs to fully compress before any of the others, and so on. Table 17 gives the dipole arm lengths and choice of balun for set frequencies. Where the test frequency does not correspond to a set frequency in the table, the arm length to be used should be determined by linear interpolation between the closest set values.

NOTE 3: The turntable should be constructed from non-conducting, low relative dielectric constant (preferably less than 1,5) material(s).

3) The measuring antenna should be connected via a 10 dB attenuator and the calibrated, ferrited coaxial cable associated with that end of the chamber, to the receiving device.

4) The test antenna (identical to the measuring antenna) should be tuned to the nominal frequency of the EUT and mounted with the height of its phase centre at the same vertical offset from the central axis of the chamber (if any) as the measuring antenna, so that the measurement axis is parallel to the central axis of the chamber. The test antenna should be oriented to the same polarization as the measuring antenna.

NOTE 4: The measurement axis is the straight line joining the phase centres of the transmitting and receiving devices.

5) The test antenna should be connected via a 10 dB attenuator and the calibrated, ferrited coaxial cable associated with that end of the chamber, to the signal generator whose output is unmodulated (see figure 40). The signal generator should be tuned to the nominal frequency of the EUT.

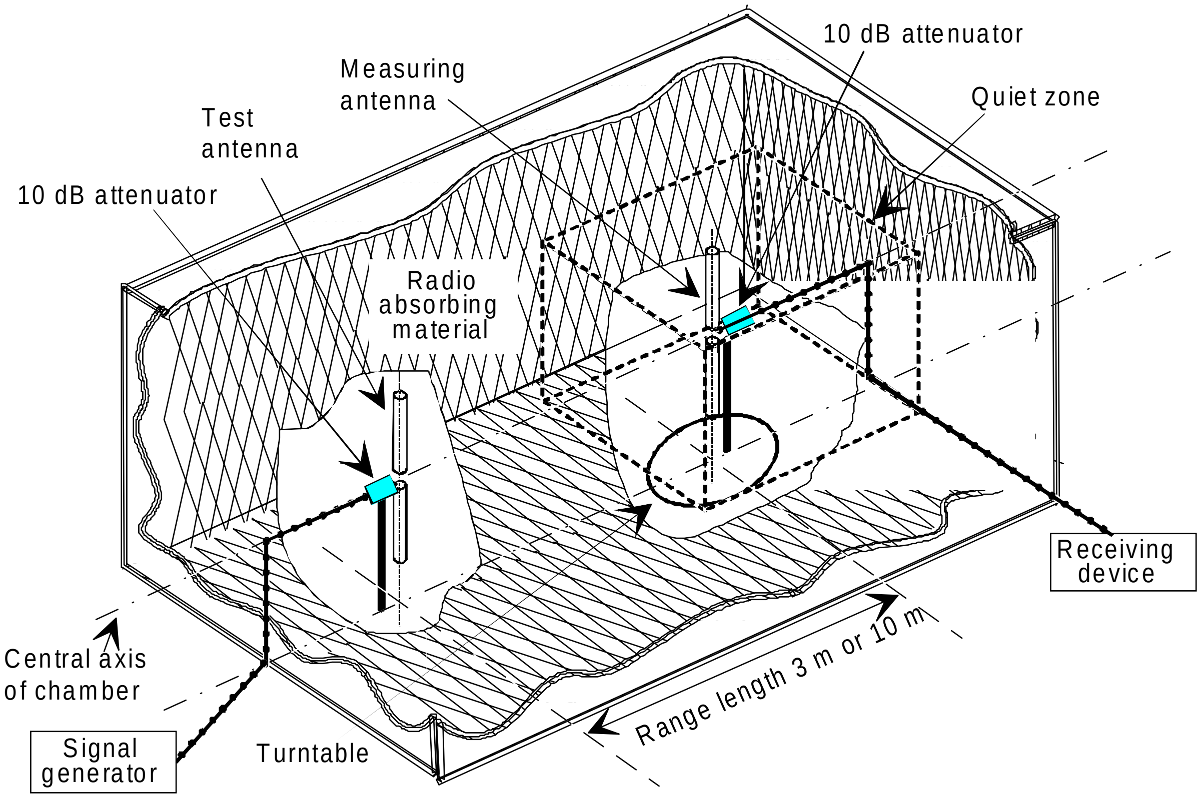

Figure 40: Equipment layout for determining the transform factor during sensitivity tests in an anechoic chamber

6) The output level of the signal generator should be adjusted until a received signal level at least 20 dB above the noise floor is observed on the receiving device.

7) The received signal level (dBμV) appearing on the receiving device along with the output level from the signal generator (dBm) should be recorded on page 2 of the log book results sheet (table 32). The transform factor for the chamber (i.e. the factor relating the output power level from the signal generator (dBm) to the resulting field strength (dBμV/m) at the point of measurement) should then be calculated according to the following formula:

Transform Factor (dB) = *received signal level (dBμV)*
+ *measuring antenna cable loss*
+ *measuring antenna attenuator loss*
+ *measuring antenna balun loss*
+ *mutual coupling and mismatch loss correction factor (if applicable)*
+ *antenna factor of the measuring antenna*
- *signal generator output level (dBm)*

NOTE 5: Guidance for deriving/calculating/finding the unknown values in the above formula for transform factor are given in table 31. These values should be entered on page 2 of the log book results sheet (table 32).

The resulting value for the transform factor should be entered on page 2 of the log book results sheet (table 32).

Table 31: Guidance for deriving Transform Factor

Values in the formula for Transform Factor	
Measuring antenna cable loss	Obtained directly from the calibration data
Measuring antenna attenuator loss	Obtained from calibration data
Measuring antenna balun loss	If not known from calibration data, the value should be taken as 0,30 dB
Mutual coupling and mismatch loss correction factors between the test antenna and the measuring antenna	For ANSI dipoles (30 to 180 MHz) values can be obtained from ETR 273-1-1 [8] table A.19. For frequencies greater than 180 MHz, this value is 0,00 dB. For non-ANSI dipoles this value is 0,00 dB
Antenna factor of the measuring antenna	For ANSI dipoles: Antenna factor = 20 $\log_{10}$ (f) - 31,4 dB dB/m (where f is the frequency in MHz) For other types the value can be obtained from calibration data

Sensitivity measurement on the EUT

8) The measuring antenna should be replaced on the turntable by the EUT. The EUT should be positioned on the turntable such that its phase centre is in the same place as formerly occupied by the phase centre of the measuring antenna.

NOTE 6: If the position of the phase centre within the EUT is unknown but the antenna is a single rod which is visible and vertical in normal usage, the axis of the antenna should be aligned with the axis of rotation of the turntable. If the phase centre is not known and there is no visible antenna the volume centre of the EUT should be aligned with the axis of rotation of the turntable.

9) The EUT should be mounted in an orientation which matches that of its normal usage as declared by the manufacturer. The normal to its reference face should point directly towards the antenna mast. This is the 0° reference angle for this test. This orientation and mounting configuration should be recorded on page 1 of the log book results sheet (table 32).

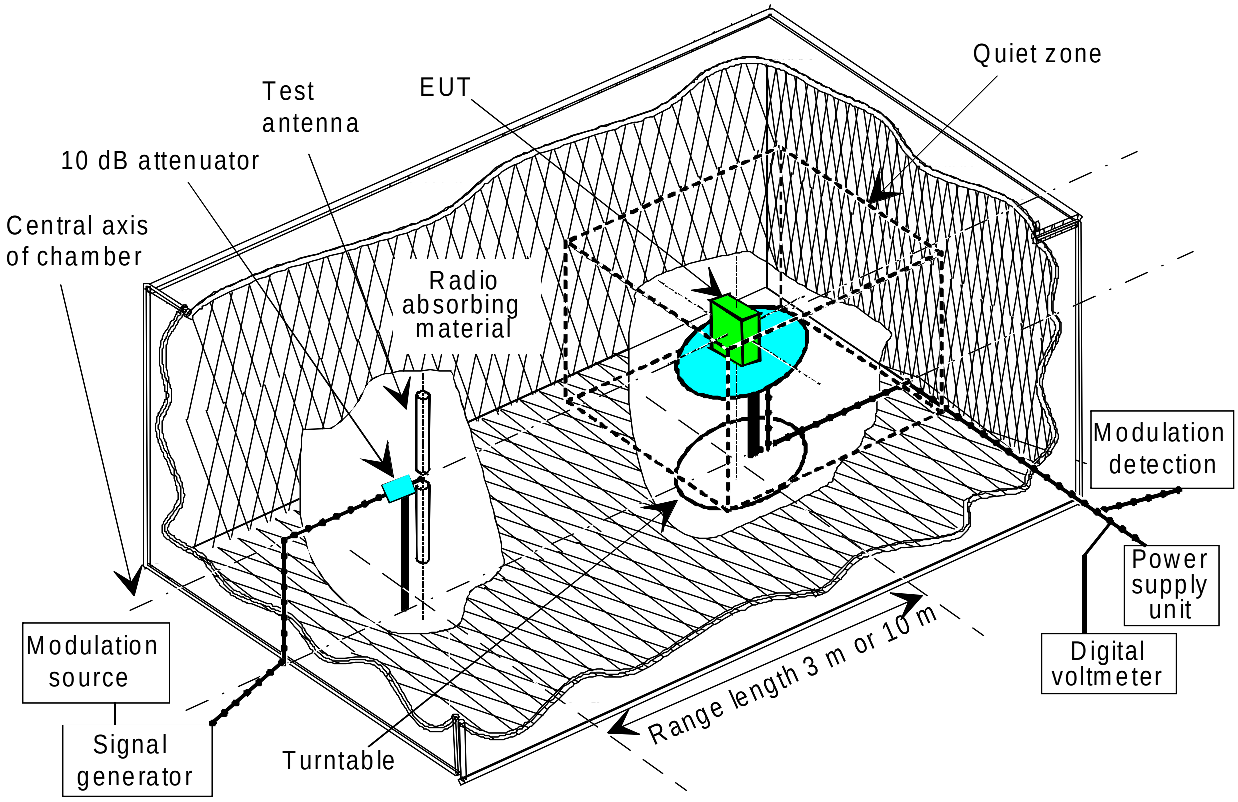

Figure 41: Anechoic chamber set-up for sensitivity tests on the EUT

For analogue speech:

10a) The EUT should be connected to the modulation detector (a SINAD meter incorporating a telephone psophometric weighting network) through an AF load or by an acoustic coupler which is made from low dielectric constant (i.e. less than 1,5) material(s) for EUTs not fitted with a direct connection (see figure 41).

10b) The signal generator output should be modulated with test modulation AM-1 (produced by the AF source) and its output level should be adjusted until a psophometrically weighted SINAD ratio of 20 dB is obtained from the EUT. The corresponding signal generator output power level should be recorded on page 2 of the log book results sheet (table 32).

10c) The EUT should be successively rotated through 45° in the horizontal plane to new testing angles of 45°, 90°, 135°, 180°, 225°, 270°, 315° (thereby covering the entire 360° in eight measurements). At each angle Step 10b should be repeated.

10d) The eight values of signal generator output power level resulting from Steps 10b and 10c should be converted into field strength values by firstly adding the transform factor to produce the field strength in dBµV/m and then secondly converting dBµV/m to µV/m i.e.:

1) field strength (dBµV/m) = signal generator level (dBm) + transform factor (dB);
2) field strength (µV/m) = $10^{(\text{field strength(dB}\mu\text{V/m)/20)}}$.

The resulting values in µV/m should be entered on page 2 of the log book results sheet (table 32).

10e) The test procedure should now continue with Step 11.

For bit stream:

10a) The EUT should be connected to the modulation detector (a bit error measuring test set, which should also receive a direct input from the bit stream generator) by a direct connection (see figure 41).

10b) The signal generator output should be modulated with test modulation DM-2 (produced by the bit stream generator) and its output level should be adjusted until a bit error ratio of 10^{-2} is obtained from the EUT. The corresponding signal generator output power level should be recorded on page 2 of the log book results sheet (table 32).

10c) The EUT should be successively rotated through 45° in the horizontal plane to new testing angles of 45°, 90°, 135°, 180°, 225°, 270°, 315° (thereby covering the entire 360° in eight measurements). At each angle Step 10b should be repeated.

10d) The eight values of signal generator output power level resulting from Steps 10b and 10c should be converted into field strength values by firstly adding the transform factor to produce the field strength in dBµV/m and then secondly converting dBµV/m to µV/m i.e.:

1) field strength (dBµV/m) = signal generator level (dBm) + transform factor (dB);
2) field strength (µV/m) = $10^{(\text{field strength(dB}\mu\text{V/m)/20)}}$.

The resulting values in µV/m should be entered on page 2 of the log book results sheet (table 32).

10e) The test procedure should now continue with Step 11.

For messages:

10a) The EUT should be connected to the modulation detector (a response measuring test set) via an acoustic coupler (pipe) which is made from low dielectric constant (i.e. less than 1,5) material(s) (see figure 41).

10b) The signal generator output should be modulated with test modulation DM-3 (produced by the message generator) and its output level should be adjusted until a message acceptance ratio of <10 % is obtained from the EUT.

10c) The test message should be transmitted repeatedly from the test antenna, whilst observing for each message whether a successful response is obtained. The output level of the signal generator should be increased by 2 dB for each occasion that a successful response is NOT obtained.

10d) Step 10c should be repeated until three consecutive successful responses are observed at the same output level from the signal generator. The output level from the signal generator should be recorded on page 2 of the log book results sheet (table 32).

10e) The output signal level from the signal generator should be reduced by 1 dB. The new signal level should be recorded on page 2 of the log book results sheet (table 32) and the response of the EUT observed.

10f) If a successful response is NOT obtained, the output signal level should be increased by 1 dB and the new level recorded in the results sheet. If a successful response IS obtained, the input level should not be changed until three consecutive successful responses have been observed. In this case, the output signal level from the signal generator should be reduced by 1 dB and the new level recorded in the results sheet. No signal levels should be recorded unless preceded by a change of level.

10g) Step 10f should be repeated until a total of 10 recorded values for the signal generator output level have been entered on page 2 of the log book results sheet (table 32).

10h) The EUT should be successively rotated through 45° in the horizontal plane to new testing angles of 45°, 90°, 135°, 180°, 225°, 270°, 315° (thereby covering the entire 360° in 8 measurements). At each angle Steps 10b to 10g should be repeated.

10i) For each angle, the ten recorded values of the signal generator output level (dBm) should be converted to field strength (µV/m) by firstly adding the transform factor to produce the field strength in dBµV/m and then secondly converting dBµV/m to µV/m i.e.:

1) field strength (dBµV/m) = signal generator level (dBm) + transform factor (dB);
2) field strength (µV/m) = $10^{(\text{field strength(dB}\mu\text{V/m)/20)}}$.

The resulting values in µV/m should be entered on page 2 of the log book results sheet (table 32).

10j) For each angle, the ten new recorded values of field strength in µV/m should be averaged according to the following formula:

$$\text{Average field strength } (\mu\text{V/m}) = \sqrt{\left(\frac{10}{\sum_{i=1}^{i=10} \frac{1}{field\ strength\ (\mu V/m)_i^{\,2}}}\right)}$$

The resulting eight average values should also be entered on page 2 of the log book results sheet (table 32).

10k) The procedure should continue with Step 11.

11) For the maximum sensitivity test only, the lowest of the eight values of field strength (µV/m) calculated during the multiple-stage Step 10 represents the minimum field strength to which the EUT responds. This minimum value of field strength (µV/m) should be entered on page 2 of the log book results sheet (table 32) as the maximum sensitivity.

12) For the average sensitivity test only, the average of the eight values of field strength (dBµV/m) calculated during the multiple-stage Step 10 represents the average field strength to which the EUT responds. This average value of field strength in µV/m should now be calculated by the following:

$$\text{Average field strength } (\mu\text{V/m}) = \sqrt{\left(\frac{8}{\sum_{i=1}^{i=8} \frac{1}{field\ strength\ (\mu V/m)_i^{\,2}}}\right)}$$

This average value of field strength (µV/m) should be entered on page 2 of the log book results sheet (table 32) as the average sensitivity.

13) Steps 2 to 12 should be repeated with both the test and measuring antennas oriented for horizontal polarization.

7.3.1.3 Procedure for completion of the results sheets

All the necessary processing of the measured results is carried out during the course of the test procedure. The only calculation that remains to be performed before the overall results sheet (table 33) can be completed is the determination of the expanded uncertainty of the measurement. This should be performed as given in subclause 7.3.2 and the resulting value entered in the overall results sheet (table 33).

7.3.1.4 Log book entries

Table 32 : Log book results sheet

RECEIVER SENSITIVITY			Date:		PAGE 1 of 2
Temperature:.........°C		**Humidity:...............%**		**Frequency:.............MHz**	
Manufacturer of EUT:....................		**Type No:..............**		**Serial No:..................**	
Range length :......................					
Test equipment item	**Type No.**	**Serial No.**	**VSWR**	**Insertion loss**	**Antenna factor**
Test antenna				N/A	
Test antenna attenuator					N/A
Test antenna cable					N/A
Measuring antenna				N/A	
Measuring antenna attenuator					N/A
Measuring antenna cable					N/A
Ferrite beads			N/A	N/A	N/A
Receiving device				N/A	N/A
Signal generator				N/A	N/A
Digital voltmeter			N/A	N/A	N/A
Power supply			N/A	N/A	N/A
AF source (if applicable)			N/A	N/A	N/A
SINAD meter (if applicable)			N/A	N/A	N/A
AF load (if applicable)			N/A	N/A	N/A
Bit stream generator (if applicable)			N/A	N/A	N/A
Bit error measuring test set (if applicable)			N/A	N/A	N/A
Acoustic coupler (if applicable)			N/A	N/A	N/A
Message generator (if applicable)			N/A	N/A	N/A
Response measuring test set (if applicable)			N/A	N/A	N/A
Mounting configuration of EUT					

(continued)

Table 32 (continued): Log book results sheet

RECEIVER SENSITIVITY (analogue speech)								Date:				PAGE 2 of 2				
Vertical polarization								**Horizontal polarization**								
Vertical offset from the central axis						m		Vertical offset from the central axis						m		
Received signal level						dBµV		Received signal level						dBµV		
Output level from signal generator						dBm		Output level from signal generator						dBm		
Transform Factor						dB		Transform Factor						dB		
Signal generator level (dBm) against angle for 20 dB SINAD								**Signal generator level (dBm) against angle for 20 dB SINAD**								
	0°	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**		**0°**	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**
level									**level**								
Conversion to µV/m									**Conversion to µV/m**								
	0°	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**		**0°**	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**
level									**level**								
MAXIMUM Sensitivity						µV/m			MAXIMUM Sensitivity						µV/m		
AVERAGE Sensitivity						µV/m			AVERAGE Sensitivity						µV/m		
Values in the formula for Transform Factor																	
Measuring antenna cable loss									Measuring antenna cable loss								
Measuring antenna attenuator loss									Measuring antenna attenuator loss								
Measuring antenna balun loss									Measuring antenna balun loss								
Mutual coupling and mismatch loss (30 - 180 MHz)									Mutual coupling and mismatch loss (30 - 180 MHz)								
Antenna factor of the measuring antenna									Antenna factor of the measuring antenna								
Vertical offset from the central axis						m			Vertical offset from the central axis						m		
Received signal level						dBµV			Received signal level						dBµV		
Output level from signal generator						dBm			Output level from signal generator						dBm		
Transform Factor						dB			Transform Factor						dB		
Signal generator level (dBm) against angle for 10^{-2} BER									**Signal generator level (dBm) against angle for 10^{-2} BER**								
	0°	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**		**0°**	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**
level									**level**								
Conversion to µV/m									**Conversion to µV/m**								
	0°	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**		**0°**	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**
level									**level**								
MAXIMUM Sensitivity						µV/m			MAXIMUM Sensitivity						µV/m		
AVERAGE Sensitivity						µV/m			AVERAGE Sensitivity						µV/m		
Values in the formula for Transform Factor																	
Measuring antenna cable loss									Measuring antenna cable loss								
Measuring antenna attenuator loss									Measuring antenna attenuator loss								
Measuring antenna balun loss									Measuring antenna balun loss								
Mutual coupling and mismatch loss (30 - 180 MHz)									Mutual coupling and mismatch loss (30 - 180 MHz)								
Antenna factor of the measuring antenna									Antenna factor of the measuring antenna								

(continued)

Table 32 (concluded): Log book results sheet

RECEIVER SENSITIVITY (messages)										Date:						PAGE 2 of 2	
Vertical polarization									**Horizontal polarization**								
Vertical offset from the central axis						m			Vertical offset from the central axis						m		
Received signal level						dBμV			Received signal level						dBμV		
Output level from signal generator						dBm			Output level from signal generator						dBm		
Transform Factor						dB			Transform Factor						dB		
Signal generator level (dBm) against angle									**Signal generator level (dBm) against angle**								
level	**0°**	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**	**level**	**0°**	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**
1									**1**								
2									**2**								
3									**3**								
4									**4**								
5									**5**								
6									**6**								
7									**7**								
8									**8**								
9									**9**								
10									**10**								
Conversion to μV/m									**Conversion to μV/m**								
level	**0°**	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**	**level**	**0°**	**45°**	**90°**	**135°**	**180°**	**225°**	**270°**	**325°**
1									**1**								
2									**2**								
3									**3**								
4									**4**								
5									**5**								
6									**6**								
7									**7**								
8									**8**								
9									**9**								
10									**10**								
Ave.									**Ave.**								
MAXIMUM Sensitivity						μV/m			MAXIMUM Sensitivity						μV/m		
AVERAGE Sensitivity						μV/m			AVERAGE Sensitivity						μV/m		
Values in the formula for Transform Factor																	
Measuring antenna cable loss									Measuring antenna cable loss								
Measuring antenna attenuator loss									Measuring antenna attenuator loss								
Measuring antenna balun loss									Measuring antenna balun loss								
Mutual coupling and mismatch loss (30 - 180 MHz)									Mutual coupling and mismatch loss (30 - 180 MHz)								
Antenna factor of the measuring antenna									Antenna factor of the measuring antenna								

7.3.1.5 Statement of results

The results should be presented in tabular form as shown in table 33.

Table 33: Overall results sheet

RECEIVER SENSITIVITY		Date:	PAGE 1 of 1
Vertical polarization		**Horizontal polarization**	
MAXIMUM Usable Sensitivity	μV/m	MAXIMUM Usable Sensitivity	μV/m
AVERAGE Usable Sensitivity	μV/m	AVERAGE Usable Sensitivity	μV/m
Expanded uncertainty (95 %)	dB	Expanded uncertainty (95 %)	dB

7.3.2 Measurement uncertainty for Receiver sensitivity

A fully worked example illustrating the methodology to be used can be found in clause 4 of ETR 273-1-2 [9].

7.3.2.1 Uncertainty contributions: Stage 1: Determination of Transform Factor

The first stage (determining the transform factor) involves placing a measuring antenna as shown in figure 42 and determining the relationship between the signal generator output power level and the resulting field strength (the shaded areas in figure 42 represent components common to both stages of the test).

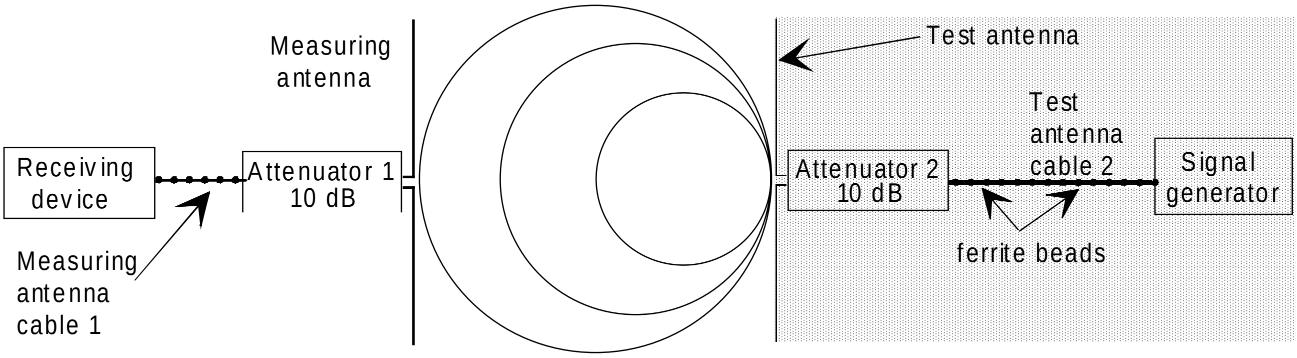

Figure 42: Stage 1: Transform Factor

All the uncertainty components which contribute to this stage of the test are listed in table 34. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 34: Contributions for the Transform Factor

uj or i	Description of uncertainty contributions	dB
u_{j36}	*mismatch: transmitting part*	0,00
u_{j37}	*mismatch: receiving part*	
u_{j38}	*signal generator: absolute output level*	
u_{j39}	*signal generator: output level stability*	
u_{j19}	*cable factor: measuring antenna cable*	
u_{j19}	*cable factor: test antenna cable*	0,00
u_{j41}	*insertion loss: measuring antenna cable*	
u_{j41}	*insertion loss: test antenna cable*	0,00
u_{j40}	*insertion loss: measuring antenna attenuator*	
u_{j40}	*insertion loss: test antenna attenuator*	0,00
u_{j47}	*receiving device: absolute level*	
u_{j16}	*range length*	0,00
u_{j02}	*reflectivity of absorber material: measuring antenna to the test antenna*	0,00
u_{j44}	*antenna: antenna factor of the measuring antenna*	
u_{j45}	*antenna: gain of the test antenna*	0,00
u_{j46}	*antenna: tuning of the measuring antenna*	
u_{j46}	*antenna: tuning of the test antenna*	0,00
u_{j22}	*position of the phase centre: measuring antenna*	
u_{j06}	*mutual coupling: measuring antenna to its images in the absorbing material*	
u_{j06}	*mutual coupling: test antenna to its images in the absorbing material*	0,00
u_{j11}	*mutual coupling: measuring antenna to the test antenna*	0,00
u_{j12}	*mutual coupling: interpolation of mutual coupling and mismatch loss correction factors*	0,00
u_{i01}	*random uncertainty*	

The standard uncertainties from table 34 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ contributions\ from\ the\ Transform\ Factor}$) for the Transform Factor in dB.

7.3.2.2 Uncertainty contributions: Stage 2: EUT measurement

The second stage (the EUT measurement) is to determine the minimum signal generator output level which produces the required response from the EUT as shown in figure 43 (the shaded areas represent components common to both stages of the test).

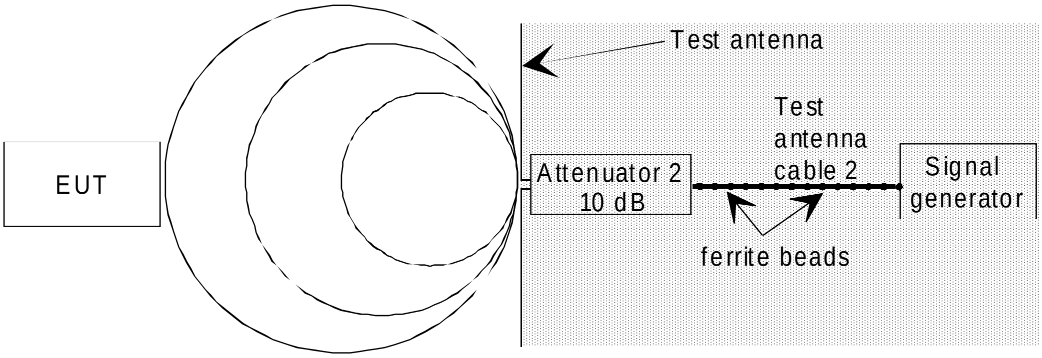

Figure 43: Stage 2: EUT measurement

All the uncertainty components which contribute to this stage of the test are listed in table 35. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 35: Contributions from the EUT measurement

$u_{j \text{ or } i}$	**Description of uncertainty contributions**	dB
u_{j36}	*mismatch: transmitting part*	
u_{j37}	*mismatch: receiving part*	
u_{j38}	*signal generator: absolute output level*	
u_{j39}	*signal generator: output level stability*	
u_{j19}	*cable factor: test antenna cable*	0,00
u_{j41}	*insertion loss: test antenna cable*	0,00
u_{j40}	*insertion loss: test antenna attenuator*	0,00
u_{j20}	*position of the phase centre: within the EUT volume*	
u_{j22}	*positioning of the phase centre: within the EUT over the axis of rotation of the turntable*	
u_{j52}	*EUT: modulation detection*	
u_{j16}	*range length*	0,00
u_{j01}	*reflectivity of absorber material: EUT to the test antenna*	
u_{j45}	*antenna: gain of the test antenna*	0,00
u_{j46}	*antenna: tuning of the test antenna*	0,00
u_{j55}	*EUT: mutual coupling to the power leads*	
u_{j08}	*mutual coupling: amplitude effect of the test antenna on the EUT*	0,00
u_{j04}	*mutual coupling: EUT to its images in the absorbing material*	
u_{j06}	*mutual coupling: test antenna to its images in the absorbing material*	0,00
u_{i01}	*random uncertainty*	

The standard uncertainties from table 35 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c \text{ contribution from the EUT measurement}}$) for the EUT measurement in dB.

7.3.2.3 Expanded uncertainty of the receiver sensitivity measurement

The combined uncertainty of the sensitivity measurement is the combination of the components outlined in subclauses 7.3.2.1 and 7.3.2.2. The components to be combined are $u_{c\ \text{contribution from the Transform Factor}}$ and $u_{c\ \text{contribution from the EUT measurement}}$.

$$u_c = \sqrt{u^2_{c\ \text{contribution from the Transform Factor}} + u^2_{c\ \text{contribution from the EUT measurement}}} = \_\_,\_\_\ \text{dB}$$

The expanded uncertainty is ± 1,96 x u_c = ± __,__ dB at a 95 % confidence level.

7.3.3 Co-channel rejection

This test is normally carried out using a test fixture and as a result has not been considered for the anechoic chamber.

7.3.4 Adjacent channel selectivity

This test is normally carried out using a test fixture and as a result has not been considered for the anechoic chamber.

7.3.5 Intermodulation immunity

This test is normally carried out using a test fixture and as a result has not been considered for the anechoic chamber.

7.3.6 Blocking immunity or desensitization

This test is normally carried out using a test fixture and as a result has not been considered for the anechoic chamber.

7.3.7 Spurious response immunity to radiated fields (30 MHz to 4 GHz)

In this test method, two signals are transmitted simultaneously towards the EUT. One is the wanted signal, whilst the other is an unwanted, interfering signal. Both signals are transmitted from the same test antenna, into which they are fed through a combining network. The wanted signal (in the range 30 MHz - 1 000 MHz) is at the nominal frequency of the receiver and is transmitted at the level specified in the ETS. The unwanted signal has a different modulation to the wanted signal and is at a very much higher power level.

Definition

The spurious response immunity to radiated fields is a measure of the capability of the receiver to discriminate between the wanted modulated radiated field at the nominal frequency and an unwanted radiated field at any other frequency at which a response is obtained.

For analogue speech: it is specified as the ratio, in decibels, of an unwanted signal level expressed as field strength to a specified wanted signal level expressed as field strength producing, through a telephone psophometric weighting network, a SINAD ratio of 14 dB.

For bit stream: it is specified as the ratio, in decibels, of an unwanted signal level expressed as field strength to a specified wanted signal level expressed as field strength producing a data signal with a bit error ratio of 10^{-2}.

For messages: it is specified as the ratio, in decibels, of an unwanted signal level expressed as field strength to a specified wanted signal level expressed as field strength producing after demodulation a message acceptance ratio of 80 %.

7.3.7.1 Apparatus required

- digital voltmeter;
- ferrite beads;
- 10 dB attenuators;
- power supply;
- connecting cables;
- combining network;
- RF load;
- power amplifier;
- 3 axis field probe;
- anechoic chamber;
- test antenna (broadband antenna recommended e.g. biconic, typically 30 MHz to 200 MHz, LPDAs, typically 200 MHz to 1 GHz and 1 GHz to 4 GHz);
- measuring antenna (half wavelength dipole as detailed in ANSI C63.5 [1] recommended);
- swept frequency RF signal generator;
- receiving device (measuring receiver or spectrum analyser);
- AF source.

Additional requirements for analogue speech:

- AF source;
- SINAD Meter (incorporating telephone psophometric weighting network);
- acoustic coupler (alternatively: audio load).

Additional requirements for bit stream:

- bit stream generator;
- bit error measuring test set.

Additional requirements for messages:

- acoustic coupler;
- message generator;
- response measuring test set.

The types and serial numbers of all items of test equipment should be recorded on page 1 of the log book results sheet (table 37).

NOTE: The half wavelength dipole antennas, incorporating matching/transforming baluns, for the procedure are available in the following bands: 20 MHz to 65 MHz, 65 MHz to 180 MHz, 180 MHz to 400 MHz, 400 MHz to 1 000 MHz. Constructional details are contained in ANSI C63.5 [1]. In the recommended antenna scheme for this band, a shortened dipole is used at all frequencies from 30 MHz up to 80 MHz.

7.3.7.2 Method of measurement

Determination of the transform factor for the anechoic chamber

1) For this part of the test, it is necessary to position either the 3-axis probe (if it possesses adequate dynamic range to allow the wanted field strength to be measured) or the measuring antenna (in the recommended scheme: a tuned ANSI C63.5 [1] half wavelength dipole for frequencies of 80 MHz and above, a shortened dipole for frequencies from 30 MHz up to 80 MHz) within the chamber such that its phase centre is at the same point that the phase centre of the EUT will occupy in the second part of the test (the EUT being mounted in an orientation which matches that of its normal usage as declared by the manufacturer). The precise point should always be on the axis of rotation of the turntable, and either on the central axis of the chamber or at a convenient height within the quiet zone. The vertical offset of the phase centre of the EUT from the central axis (if any) should be either measured remotely or determined by sitting the EUT on the turntable. The offset should be recorded on page 2 of the log book results sheet (table 37).

NOTE 1: If the position of the phase centre within the EUT is unknown but the antenna is visible, then the vertical offset from the central axis of the point at which the antenna meets the case of the EUT should be used. If the phase centre is unknown and there is no visible antenna the volume centre of the EUT should be used instead.

NOTE 2: If a 3-axis probe is being used to measure the field strength of the wanted signal, Step 2 and 3 should be omitted.

2) The measuring antenna should be adjusted to correspond to the nominal frequency of the EUT and positioned with its phase centre on the axis of rotation of the turntable and at the same vertical offset from the central axis of the chamber (if any) as determined for the EUT in Step 1. The measuring antenna should be oriented for vertical polarization.

NOTE 3: For all frequencies below 80 MHz, a shortened dipole (as defined in subclause 7.1.3) should be used. The dipole arm length is defined from the centre of the balun block to the tip of the arm. From a fully extended state, each telescopic element, in turn, should be "pushed in" from the tip until the required length is obtained. The outermost section needs to fully compress before any of the others, and so on. Table 17 gives the dipole arm lengths and choice of balun for set frequencies. Where the test frequency does not correspond to a set frequency in the table, the arm length to be used should be determined by linear interpolation between the closest set values.

NOTE 4: The turntable should be constructed from non-conducting, low relative dielectric constant (preferably less than 1,5) material(s).

3) The measuring antenna should be connected via a 10 dB attenuator and the calibrated, ferrited coaxial cable associated with that end of the chamber, to the receiving device.

4) The test antenna (a broadband antenna which is functional at both the nominal frequency of the EUT as well as covering either the calculated frequency at which a spurious response may occur or part of the limited frequency range) should be tuned to the nominal frequency of the EUT and mounted with the height of its phase centre at the same vertical offset from the central axis of the chamber (if any) as recorded in Step 1, so that the measurement axis is parallel to the central axis of the chamber. The test antenna should be oriented to the same polarization as the measuring antenna.

NOTE 5: The measurement axis is the straight line joining the phase centres of the transmitting and receiving devices.

5) The test antenna should be connected via a 10 dB attenuator and the calibrated, ferrited coaxial cable associated with that end of the chamber, to signal generator A (see figure 44) via the combiner whose other port should be terminated with the RF load. The output from signal generator A should be unmodulated and tuned to the nominal frequency of the EUT.

NOTE 6: Steps 6 and 7 should be omitted if a 3-axis probe is being used to measure the wanted field strength.

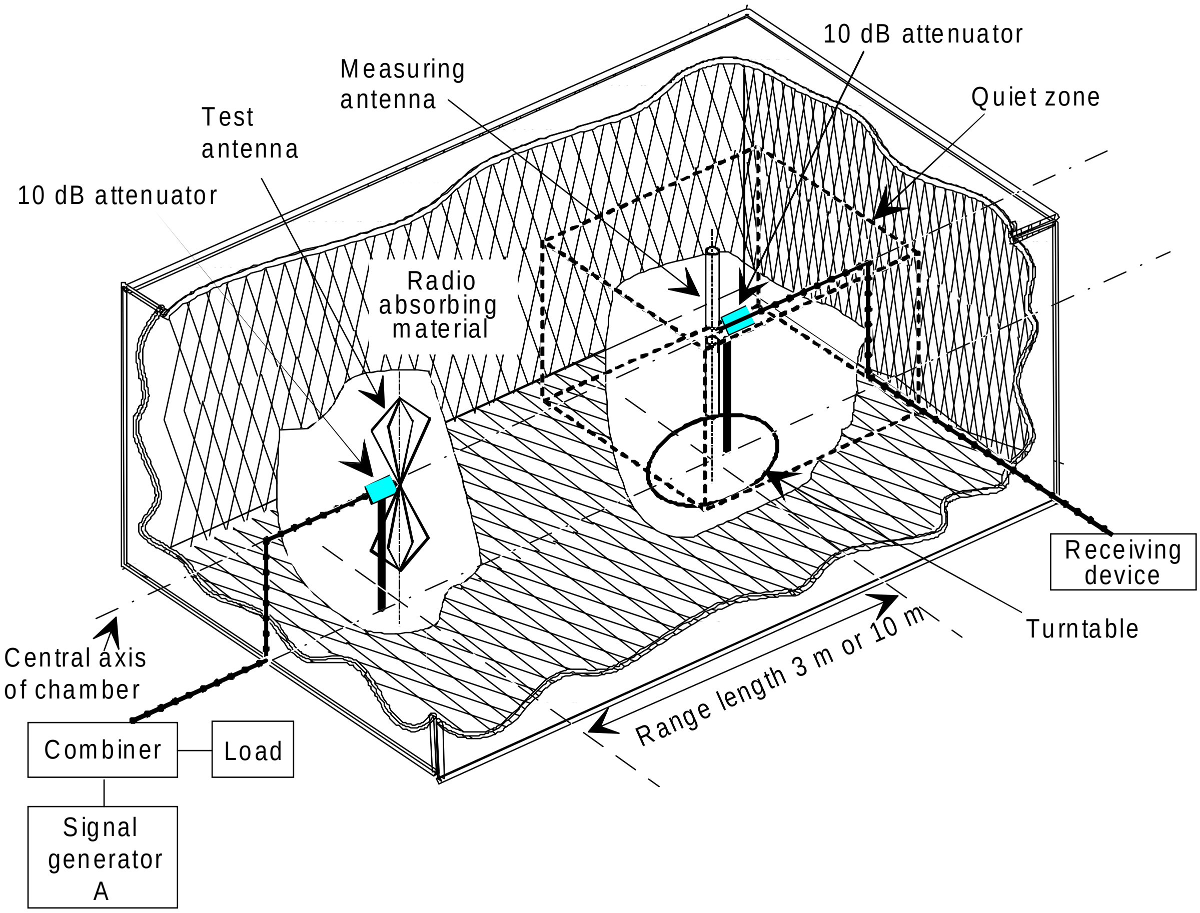

Figure 44: Equipment layout for determining the transform factor in an anechoic chamber (using a measuring antenna)

6) The output level of the signal generator A should be adjusted until a received signal level at least 20 dB above the noise floor is observed on the receiving device.

7) The received signal level (dBµV) appearing on the receiving device along with the output level from the signal generator (dBm) should be recorded on page 2 of the log book results sheet (table 37). The transform factor for the chamber (i.e. the factor relating the output power level from the signal generator (dBm) to the resulting field strength (dBµV/m) at the point of measurement) should then be calculated according to the following formula:

Transform Factor (dB) = *received signal level (dBµV)*
\+ *measuring antenna cable loss*
\+ *measuring antenna attenuator loss*
\+ *measuring antenna balun loss*
\+ *mutual coupling and mismatch loss correction factor (if applicable)*
\+ *antenna factor of the measuring antenna*
\- *signal generator output level (dBm)*

NOTE 7: Guidance for deriving/calculating/finding the unknown values in the above formula for transform factor are given in table 36. The resulting values should be entered on page 2 of the log book results sheet (table 37).

The resulting value for the transform factor should be entered on page 2 of the log book results sheet (table 37).

Table 36: Guidance for deriving Transform Factor

Values in the formula for Transform Factor	
Measuring antenna cable loss	Obtained directly from the calibration data
Measuring antenna attenuator loss	Obtained from calibration data
Measuring antenna balun loss	If not known from calibration data, the value should be taken as 0,30 dB.
Mutual coupling and mismatch loss correction factors between the test antenna and the measuring antenna	For ANSI dipoles (30 to 180 MHz) values can be obtained from ETR 273-1-1 [8] table A19. For frequencies greater than 180 MHz, this value is 0,00 dB. For non-ANSI dipoles this value is 0,00 dB
Antenna factor of the measuring antenna	For ANSI dipoles: Antenna factor = 20 $\log_{10}$ (*f*) - 31,4 dB dB/m (where *f* is the frequency in MHz) For other types the value can be obtained from calibration data

8) If a measuring antenna is being used, the output power level of the signal generator (dBm) should be adjusted, using the calculated value for the transform factor, to provide the wanted signal level (dBµV/m, as specified in the relevant testing standard) in the vicinity of the EUT. Alternatively, if a 3-axis probe is being used to measure the field strength, the output power level of the signal generator (dBm) should be adjusted to provide the wanted signal level (dBµV/m, as specified in the relevant testing standard).

EUT set-up

9) The 3-axis probe or measuring antenna should be replaced on the turntable by the EUT. The EUT should be positioned on the turntable such that its phase centre is in the same place as formerly occupied by the centre of the 3-axis probe or the phase centre of the measuring antenna.

NOTE 8: If the position of the phase centre within the EUT is unknown but the antenna is a single rod which is visible and vertical in normal usage, the axis of the antenna should be aligned with the axis of rotation of the turntable. If the phase centre is not known and there is no visible antenna the volume centre of the EUT should be aligned with the axis of rotation of the turntable.

10) The EUT should be mounted in an orientation which matches that of its normal usage as declared by the manufacturer. The normal to its reference face should point directly towards the test antenna. This is the 0° reference angle for the test. This orientation and mounting configuration should be recorded on page 1 of the log book results sheet (table 37).

Measurement of the EUT

11) The two signal generators should be connected to the test antenna as shown in figure 45. Signal generator A provides the wanted signal. It should remain at the level set in Step 8 and at the nominal frequency of the EUT. Signal generator B and the power amplifier provide the interfering, unwanted signal. Test modulation A-M3, produced by an AF source, should be applied to the modulator input of signal generator B which should be tuned to the lowest frequency of the limited frequency range (defined in the relevant testing standard).

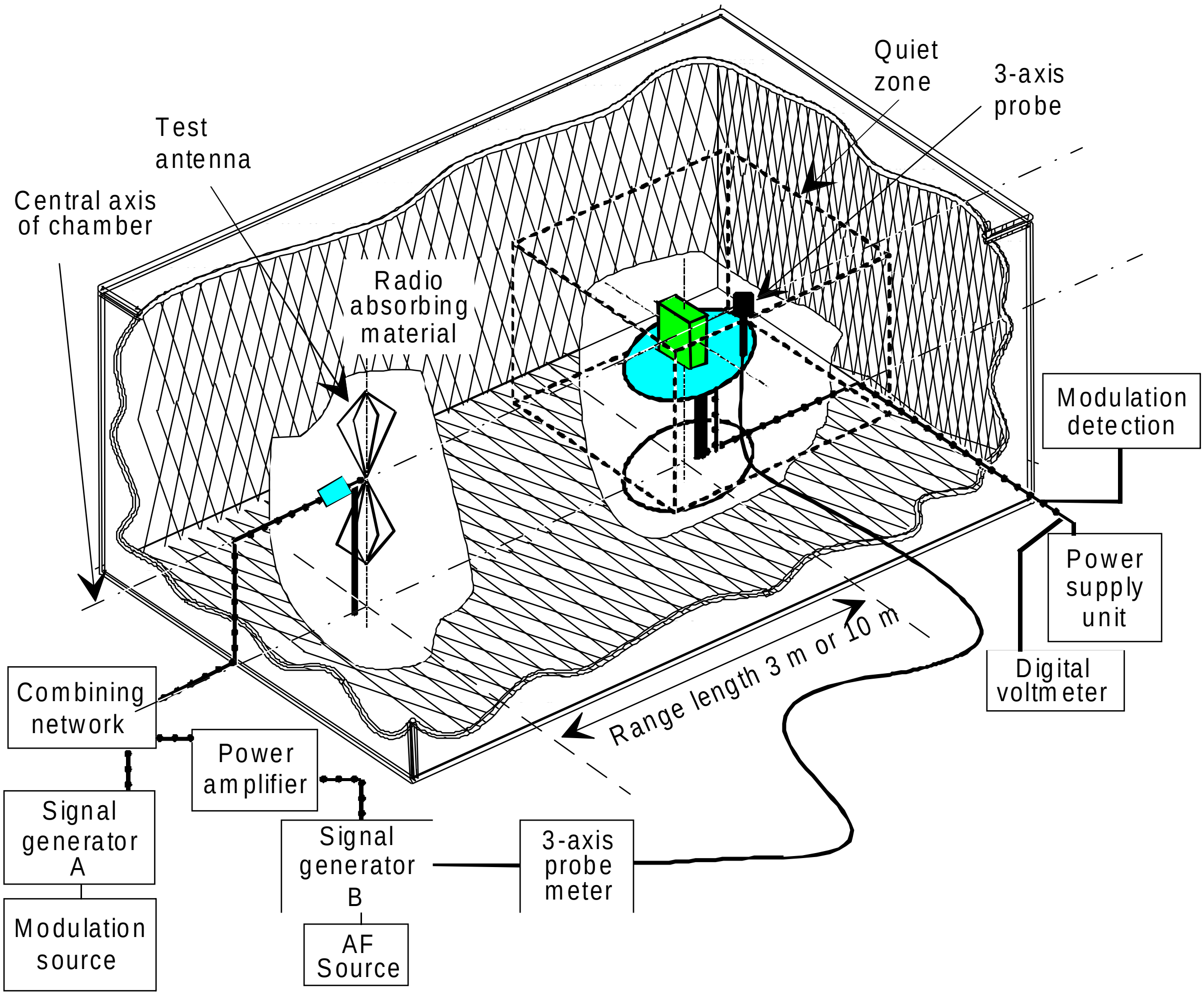

Figure 45: Anechoic chamber set-up for Spurious response immunity tests

For analogue speech:

12a) Signal generator A should be modulated with test modulation A-M1 produced by the AF source. Signal generator B should then have its level adjusted to give a field strength, as measured by the 3-axis probe, which is 80 dB in excess of the *wanted signal level*. The output power of signal generator B should then be levelled at this field strength, using the 3-axis probe, to ensure that at any frequency, the generated field strength is the same. The frequency of the unwanted signal should then be continuously varied over the entire *limited frequency range* noting any frequencies which degrade the SINAD ratio below 20 dB. These frequencies should be recorded on page 2 of the log book results sheet (table 37).

NOTE 9: The response time of the SINAD meter should be taken into account when deciding the sweep speed for signal generator B.

12b) In turn, signal generator B should be tuned to each of the frequencies recorded in Step 12a as well as to those frequencies outside the *limited frequency range* at which it has been calculated that a response may occur. At each frequency, the output power level of signal generator B should be adjusted to provide a 14 dB SINAD ratio from the EUT. The corresponding value of field strength (µV/m), as measured on the 3-axis probe, should be recorded on page 2 of the log book results sheet (table 37).

NOTE 10: The field strength measurement on the unwanted signal can be made despite the presence of the wanted signal since its magnitude is greatly in excess of that for the wanted signal.

12c) The spurious response immunity ratio to radiated fields for analogue speech should be calculated, for each of the frequencies concerned, as the ratio in dB of the field strength of the unwanted signal to the *wanted signal level* at the receiver input and should be recorded on page 2 of the log book results sheet (table 37).

12d) The procedure should continue with subclause 7.3.7.3.

For bit stream:

12a) Signal generator A should be modulated with test modulation D-M2 produced by the bit stream generator. The reference bit stream output from the bit stream generator should be connected to the reference bit stream input on the bit error detector. Signal generator B should then be adjusted to give a field strength, as measured by the 3-axis probe, which is 80 dB in excess of the *wanted signal level*. The output power of signal generator B should then be levelled at this field strength, using the 3-axis probe, to ensure that at any frequency, the generated field strength is the same. The frequency of the unwanted signal should then be continuously varied over the entire *limited frequency range* noting any frequencies which produce a response i.e. a change in bit error ratio. These frequencies should be recorded on page 2 of the log book results sheet (table 37).

NOTE 11: The response time of the bit error measuring test set should be taken into account when deciding the sweep speed for signal generator B.

12b) In turn, signal generator B should be tuned to each of the frequencies recorded in Step 12a as well as to those frequencies outside the *limited frequency range* at which it has been calculated that a response may occur. At each frequency, the output power level of signal generator B should be adjusted to provide a bit error ratio of 10^{-2} from the EUT. The corresponding value of field strength (µV/m), as measured on the 3-axis probe, should be recorded on page 2 of the log book results sheet (table 37).

12c) The spurious response immunity ratio to radiated fields for bit stream should be calculated, for each of the frequencies concerned, as the ratio in dB of the field strength of the unwanted signal to the *wanted signal level* at the receiver input and should be recorded on page 2 of the log book results sheet (table 37).

12d) The procedure should continue with subclause 7.3.7.3.

For messages:

12a) The EUT should be monitored via an acoustic coupler (pipe) which is made from low dielectric constant (i.e. less than 1,5) material(s) for message acceptance.

NOTE 12: The test sequence which ensures the 80 % message acceptance criterion is very time consuming. It is considered impractical to combine this test sequence with a continuous frequency sweep (as occurs in the corresponding procedures for analogue speech and bit stream data) since the sweep speed for signal generator B would have to be extremely slow to allow capture of narrow band spurious responses. Therefore the test is carried out for the calculated response frequencies only.

12b) Signal generator A should be modulated with test modulation D-M3 produced by the message generator and signal generator B should be tuned to the first frequency for which it has been calculated that a response might occur.

12c) The wanted signal should then be transmitted repeatedly and the unwanted signal switched on. The input level of the unwanted signal should be adjusted until a message acceptance ratio of less than 10 % is obtained.

12d) The level of the unwanted signal should be reduced by 2 dB for each occasion that a successful response is not observed. This procedure should be continued until three consecutive successful responses have been observed. The value of field strength as indicated by the 3-axis probe should then be recorded on page 2 of the log book results sheet (table 37).

12e) The unwanted signal level should be increased by 1 dB and the new value of field strength recorded on page 2 of the log book results sheet (table 37). The wanted signal should then be continuously repeated. In each case if a response is NOT obtained the level of the unwanted signal should be reduced by 1 dB and the new field strength value recorded in the results sheet. If a successful response IS obtained, the level of the unwanted signal should not be changed until three consecutive successful responses have been obtained. In this case the unwanted signal should be increased by 1 dB and the new field strength value recorded on page 2 of the log book results sheet (table 37). No levels of the field strength should be recorded unless preceded by a change in level. The measurement should be stopped after a total of 10 values have been recorded.

12f) The ten values of field strength recorded during Steps 12d and 12e should then be averaged according to the following formulation:

$$\text{Average field strength } (\mu\text{V/m}) = \sqrt{\left(\frac{10}{\sum_{i=1}^{i=10} \frac{1}{field\ strength\ (\mu V/m)_i^{\ 2}}} \right)}$$

12g) Steps 12c to 12f should be repeated at each frequency within the specified frequency range at which it is calculated that a spurious response could occur.

12h) The spurious response immunity to radiated fields for messages should be calculated, for the frequency concerned, as the ratio in dB of the average field strength of the unwanted signal (Step 12f) to the wanted signal level at the receiver input and should be recorded on page 2 of the log book results sheet (table 37).

12i) The procedure should continue with subclause 7.3.7.3.

7.3.7.3 Procedure for completion of the results sheets

No special processing of the results is necessary to provide the spurious response immunity, since all calculations are performed during the procedure. However, to complete the overall results sheet (table 38) it is necessary, firstly to transfer some or all of the response frequencies and their corresponding values for spurious response immunity and secondly to calculate the expanded measurement uncertainty associated with the procedure. This should be carried out as detailed in subclause 7.3.8.

7.3.7.4 Log book entries

Table 37: Log book results sheet

SPURIOUS RESPONSE IMMUNITY			**Date:**		**Page 1 of 2**
Temperature:.........°C	**Humidity:..............%**			**Frequency:............MHz**	
Manufacturer of EUT:....................	**Type No:.............**			**Serial No:.................**	
Range length :......................					
Test equipment item	Type No.	Serial No.	VSWR	Insertion loss	Antenna factor
Test antenna				N/A	
Test antenna attenuator					N/A
Test antenna cable					N/A
Measuring antenna				N/A	
Measuring antenna attenuator					N/A
Measuring antenna cable					N/A
Ferrite beads			N/A	N/A	N/A
Combining network				N/A	N/A
RF load				N/A	N/A
Signal generator				N/A	N/A
Digital voltmeter			N/A	N/A	N/A
Power supply			N/A	N/A	N/A
Frequency modulation source			N/A	N/A	N/A
AF source (if applicable)			N/A	N/A	N/A
SINAD meter (if applicable)			N/A	N/A	N/A
AF load (if applicable)			N/A	N/A	N/A
Bit stream generator (if applicable)			N/A	N/A	N/A
Bit error measuring test set (if applicable)			N/A	N/A	N/A
Acoustic coupler (if applicable)			N/A	N/A	N/A
Message generator (if applicable)			N/A	N/A	N/A
Response measuring test set (if applicable)			N/A	N/A	N/A
Mounting configuration of EUT					

(continued)

Table 37 (continued): Log book results sheet

SPURIOUS RESPONSE IMMUNITY (analogue speech)		Date:	Page 2 of 2
Vertical offset from the central axis			m
Received signal level			dBµV
Signal generator output level			dBm
Transform Factor			dB
Wanted signal level: µV/m		**Limited frequency range:** MHz	
Response and calculated frequencies (MHz)	**Field strength of unwanted signal for 14 dB SINAD (µV/m)**	**Spurious response immunity: Field strength of unwanted signal - Wanted signal level (dB)**	
Values in the formula for Transform Factor			
Measuring antenna cable loss		Measuring antenna cable loss	
Measuring antenna attenuator loss		Measuring antenna attenuator loss	
Measuring antenna balun loss		Measuring antenna balun loss	
Mutual coupling and mismatch loss (30 - 180 MHz)		Mutual coupling and mismatch loss (30 - 180 MHz)	
Antenna factor of the measuring antenna		Antenna factor of the measuring antenna	

SPURIOUS RESPONSE IMMUNITY (bit stream)		Date:	Page 2 of 2
Vertical offset from the central axis			m
Received signal level			dBµV
Signal generator output level			dBm
Transform Factor			dB
Wanted signal level: µV/m		**Limited frequency range:** MHz	
Response and calculated frequencies (MHz)	**Field strength of unwanted signal for 10^{-2} BER (µV/m)**	**Spurious response immunity:** Field strength of unwanted signal - Wanted signal level (dB)	
Values in the formula for Transform Factor			
Measuring antenna cable loss		Measuring antenna cable loss	
Measuring antenna attenuator loss		Measuring antenna attenuator loss	
Measuring antenna balun loss		Measuring antenna balun loss	
Mutual coupling and mismatch loss (30 - 180 MHz)		Mutual coupling and mismatch loss (30 - 180 MHz)	
Antenna factor of the measuring		Antenna factor of the measuring	

antenna		antenna	

(continued)

Table 37 (concluded): Log book results sheet

SPURIOUS RESPONSE IMMUNITY (messages)		**Date:**	**Page 2 of 2**
Vertical offset from the central axis			m
Received signal level			dBμV
Signal generator output level			dBm
Transform Factor			dB
Wanted signal level:	μV/m	**Limited frequency range:**	MHz
Calculated frequencies (MHz)	**Field strength of unwanted signal for 80 % acceptance (μV/m)**	**Spurious response immunity:** Field strength of unwanted signal - Wanted signal level (dB)	
Values in the formula for Transform Factor			
Measuring antenna cable loss		Measuring antenna cable loss	
Measuring antenna attenuator loss		Measuring antenna attenuator loss	
Measuring antenna balun loss		Measuring antenna balun loss	
Mutual coupling and mismatch loss (30 - 180 MHz)		Mutual coupling and mismatch loss (30 - 180 MHz)	
Antenna factor of the measuring antenna		Antenna factor of the measuring antenna	

7.3.7.5 Statement of results

The results should be presented in tabular form as shown in table 38.

Table 38: Overall results sheet

SPURIOUS RESPONSE IMMUNITY	**Date:** **Page 1 of 1**
Frequency (MHz)	**Spurious response immunity (dB)**
Expanded uncertainty (95 %)	dB

7.3.8 Measurement uncertainty for Spurious response immunity

A fully worked example for the measurement uncertainty involved in this test has not been given in clause 4 0f ETR 273-1-2 [9], although the procedure is basically the same as those given.

7.3.8.1 Uncertainty contributions: Stage 1: Transform factor

If the first stage involved measuring the transform factor (as shown in figure 46) i.e. the relationship between the output level of the signal generator (dBm) and the resulting field strength (dBμV/m) in the vicinity of the turntable, then the shaded areas in figure 46 represent components common to both stages of the test.

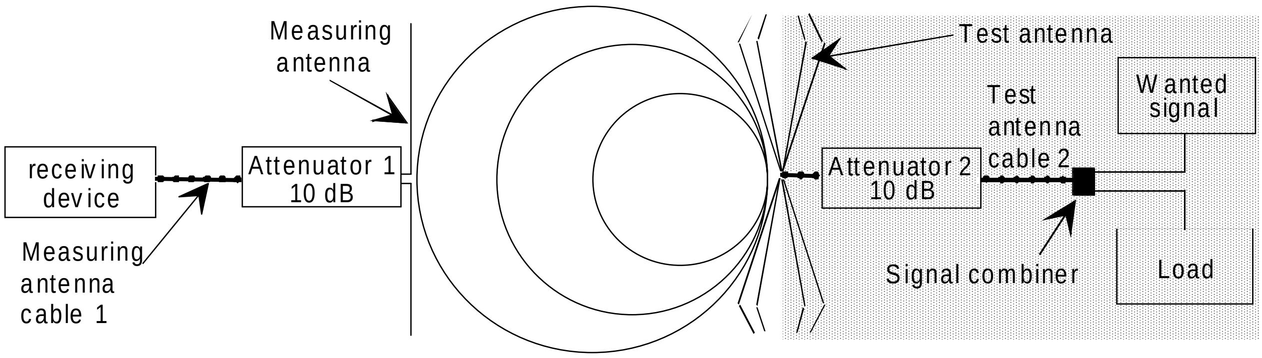

Figure 46: Stage 1: Transform factor

All the uncertainty components which contribute to this stage of the test are listed in table 39. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

Table 39: Contributions for the Transform Factor

uj or i	Description of uncertainty contributions	dB
u_{j36}	*mismatch: transmitting part*	
u_{j37}	*mismatch: receiving part*	
u_{j38}	*signal generator: absolute output level*	
u_{j39}	*signal generator: output level stability*	
u_{j19}	*cable factor: measuring antenna cable*	
u_{j19}	*cable factor: test antenna cable*	
u_{j41}	*insertion loss: measuring antenna cable*	
u_{j41}	*insertion loss: test antenna cable*	0,00
u_{j40}	*insertion loss: measuring antenna attenuator*	
u_{j40}	*insertion loss: test antenna attenuator*	0,00
u_{j47}	*receiving device: absolute level*	
u_{j16}	*range length*	0,00
u_{j02}	*reflectivity of absorber material: measuring antenna to the test antenna*	0,00
u_{j44}	*antenna: antenna factor of the measuring antenna*	
u_{j45}	*antenna: gain of the test antenna*	0,00
u_{j46}	*antenna: tuning of the measuring antenna*	
u_{j46}	*antenna: tuning of the test antenna*	0,00
u_{j22}	*position of the phase centre: measuring antenna*	
u_{j06}	*mutual coupling: measuring antenna to its images in the absorbing material*	
u_{j06}	*mutual coupling: test antenna to its images in the absorbing material*	0,00
u_{j11}	*mutual coupling: measuring antenna to the test antenna*	0,00
u_{j12}	*mutual coupling: interpolation of mutual coupling and mismatch loss correction factors*	0,00
u_{i01}	*random uncertainty*	

Alternatively, if the 3-axis probe was used, then figure 47 illustrates the test equipment set-up and table 40 lists the uncertainty components that contribute.

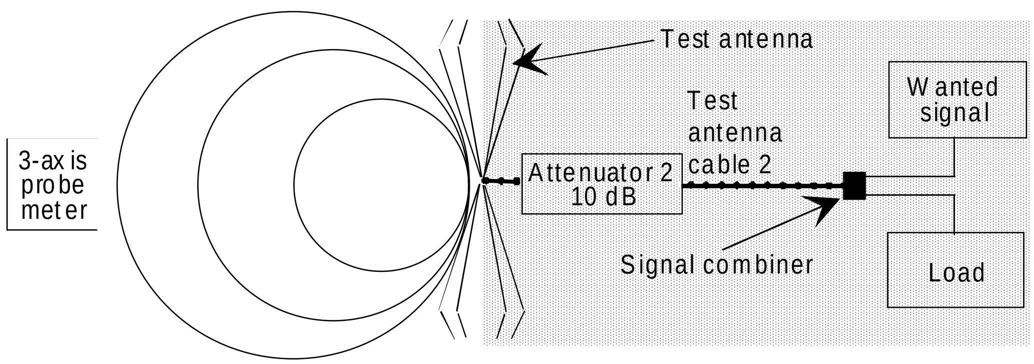

Figure 47: Stage 1: 3-axis probe

Table 40: Contributions for the 3-axis probe

uj or i	Description of uncertainty contributions	dB
u_{j36}	*mismatch: transmitting part*	0,00
u_{j38}	*signal generator: absolute output level*	0,00
u_{j39}	*signal generator: output level stability*	
u_{j19}	*cable factor: test antenna cable*	
u_{j41}	*insertion loss: test antenna cable*	0,00
u_{j40}	*insertion loss: test antenna attenuator*	0,00
u_{j16}	*range length*	
u_{j45}	*antenna: gain of the test antenna*	0,00
u_{j46}	*antenna: tuning of the test antenna*	0,00
u_{j06}	*mutual coupling: test antenna to its images in the absorbing material*	0,00
u_{j12}	*mutual coupling: interpolation of mutual coupling and mismatch loss correction factors*	0,00
u_{j28}	*field strength measurement as determined by the 3-axis probe*	
u_{i01}	*random uncertainty*	

The standard uncertainties from table 39 of table 40 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ contributions\ from\ the\ Transform\ Factor}$) for the transform factor in dB.

7.3.8.2 Uncertainty contributions: Stage 2: EUT measurement

In this stage, the wanted signal is set to the level specified in the standard using either the transform factor of the three-axis probe. The unwanted signal is then switched on and the level adjusted until the level of the unwanted signal, as measured on the three-axis probe, is at the wanted signal level plus the spurious response rejection ratio required. The schematic of the equipment set-up is shown in figure 48.

All the uncertainty components that contribute to this stage of the test are listed in table 41. Annex A should be consulted for the sources and/or magnitudes of the uncertainty contributions.

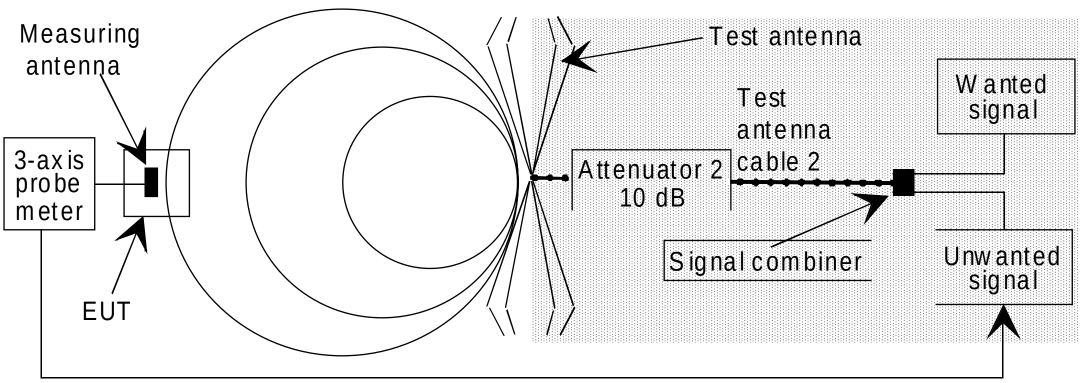

Figure 48: Stage 2: EUT measurement

Table 41: Contributions from the EUT measurement

uj or i	Description of uncertainty contributions	dB
u_{j20}	*position of the phase centre: within the EUT volume*	
u_{j52}	*EUT: modulation detection*	
u_{j28}	*field strength measurement as determined by the 3-axis probe (unwanted signal measurement)*	
u_{i01}	*random uncertainty*	

The standard uncertainties from table 41 should be combined by RSS in accordance with clause 5 of ETR 273-1-1 [8]. This gives the combined standard uncertainty ($u_{c\ contribution\ from\ the\ EUT\ measurement}$) for the EUT measurement in dB.

7.3.8.3 Expanded uncertainty of the spurious response immunity measurement

The combined uncertainty of the spurious response immunity measurement is the combination of the components outlined in subclauses 7.3.8.1 and 7.3.8.2. The components to be combined are($u_{c\ contribution\ from\ the\ Transform\ Factor}$ and $u_{c\ contribution\ from\ the\ EUT\ measurement}$.

$$u_c = \sqrt{u^2_{c\,contribution\ from\,the\,Transform\ Factor} + u^2_{c\,contribution\ from\,the\,EUT\ measurement}} = \_\_,\_\_ \text{ dB}$$

The expanded uncertainty is ± 1,96 x u_c = ± __,__ dB at a 95 % confidence level.

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