IEC 62431

Edition 1.0 2008-07

INTERNATIONAL STANDARD

Reflectivity of electromagnetic wave absorbers in millimetre wave frequency – Measurement methods

IEC 62431:2008(E)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE XA

ICS 19.080; 17.120; 29.120.10

ISBN 2-8318-9895-1

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

REFLECTIVITY OF ELECTROMAGNETIC WAVE ABSORBERS IN MILLIMETRE WAVE FREQUENCY – MEASUREMENT METHODS

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IEC 62431 replaces and cancels IEC/PAS 62431 with corrections of obvious errors as noted in 46F/29A/RVN.

The text of this standard is based on the following documents:

CDV	Report on voting
46F/65/CDV	46F/72/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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A bilingual version of this publication may be issued at a later date.

REFLECTIVITY OF ELECTROMAGNETIC WAVE ABSORBERS IN MILLIMETRE WAVE FREQUENCY – MEASUREMENT METHODS

1 Scope

This International Standard specifies the measurement methods for the reflectivity of electromagnetic wave absorbers (EMA) for the normal incident, oblique incident and each polarized wave in the millimetre-wave range. In addition, these methods are also equally effective for the reflectivity measurement of other materials:

– measurement frequency range: 30 GHz to 300 GHz;
– reflectivity: 0 dB to –50 dB;
– incident angle: 0° to 80°.

NOTE This standard is applicable not only to those EMA which are widely used as counter-measures against communication faults, radio interference etc. , but also to those used in an anechoic chamber in some cases. EMAs may be any kind of material, and may have any arbitrary shape, configuration, or layered structure as pointed out below.

Material: Conductive material, dielectric material, magnetic material.

Shape: planar-, pyramidal-, wedge-type, or other specific shapes.

Layer structure: single layer, multi layers, or graded-index material.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms, definitions and acronyms

For the purposes of this document, the following terms and definitions apply.

3.1 Terms and definitions

3.1.1
ambient level
the value of radiation power or noise which exists when no measurement is being carried out at the experiment site

3.1.2
associated equipment
an apparatus or product connected for convenience or operation of the equipment

3.1.3
beam diameter
the diameter where the electric field strength decreases by 3 dB from the centre of the focused beam

3.1.4
beam waist
the portion at which the diameter of the focused beam becomes minimum when the electromagnetic waves radiated from a transmit antenna are converged using a dielectric lens

3.1.5
beam waist diameter
beam diameter at the beam waist

3.1.6
bistatic measurement
measurement where the incident and reflection angle are equal

3.1.7
dielectric lens
electromagnetic wave lens that is composed of dielectric material

Usually, it is used by mounting in front of a pyramidal or conical horn.

3.1.8
directional gain
ratio of the radiated power density in a particular direction to the average power density that would be radiated in all directions

3.1.9
dynamic range
difference in decibels between the receiving level from the reference metal plate and the receiving level measured when the metal plate is removed

3.1.10
electromagnetic wave absorber
material ingredient which absorbs the electromagnetic wave energy and dissipates it thermally

3.1.11
focal distance
distance between the centre of the dielectric lens and the focal point

3.1.12
focal point
centre of the beam waist when the electromagnetic waves are converged using a dielectric lens

3.1.13
focused beam
focused electromagnetic wave converged by the dielectric lens mounted in front of the horn antenna

The focused beam diameter is a few times the wavelength or more at the beam waist, which depends on the focal distance of the lens.

3.1.14
fraunhofer region
region where the angular radiation pattern of an aperture antenna is nearly independent of the distance

3.1.15
free-space method
measurement method that employs a single or pair of horn antennas where the specimen and the antennas are put in free space

3.1.16
fresnel region
region where the angular radiation pattern of an aperture antenna depends on the distance except for the region extremely near to the aperture

3.1.17
horn antenna
aperture antenna where impedance matching is taken gradually from the waveguide aperture to free space

3.1.18
monostatic measurement
measurement where the incident and reflected waves follow the same direction and which lie at an arbitrary angle with respect to normal to the specimen surface

3.1.19
normal incidence
the incidence for which an electromagnetic wave strikes to the specimen surface normally

The reflectivity in normal incidence is usually measured in the configuration where the incident angle of a transmitting antenna and that of a receiving antenna are within 0° to 5° with respect to the normal direction of the specimen surface.

3.1.20
oblique incidence
the incidence for which an electromagnetic wave strikes to the specimen surface at an oblique angle

The reflectivity in oblique incidence is usually measured with a transmitting and receiving antenna set up so that the incident and reflected angle of EM wave may be equal.

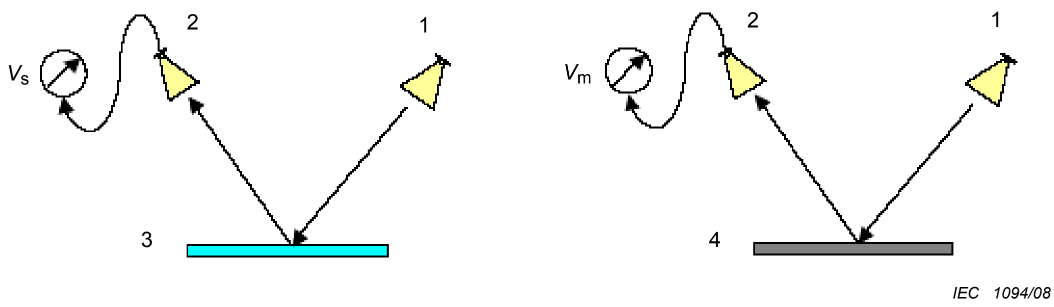
3.1.21
parallel beam
EM wave, which has a nearly flat phase front on the surface normal to the antenna axis, and which is formed using a dielectric lens set-up in front of a horn antenna

3.1.22
reference metal plate
metal plate with the same shape and an equal surface projected area in normal to the specimen

3.1.23
reflectivity
the ratio between reflected EM wave voltage received by the receiving antenna when a specimen is irradiated by the EM wave, and the voltage of the EM wave reflected from a metal plate with equal size and with the same projection shape in normal to the specimen surface expressed in decibel by

$$\text{reflectivity} = 20\log_{10}\left|\frac{V_S}{V_m}\right| = 20\log_{10}|V_S| - 20\log_{10}|V_m| \text{ [dB]} \quad (1)$$

where V_s is the reflected EM wave voltage received by the receiving antenna when a specimen is irradiated by the EM wave, and V_m is the voltage of the EM wave reflected from a metal plate with equal size and with the same projection shape in normal to the specimen surface. See Figure 1.



Key

1 Tx antenna

2 Rx antenna

3 EMA

4 Metal plate

Figure 1 – Definition of reflectivity

3.1.24
time domain function
a function that is implemented in VNA to transform the measured frequency domain data to time evolution data using inverse Fourier transform because the VNA can measure both the amplitude and phase of EM wave

Using this function, the reflected wave only from the specimen can be extracted by applying a suitable time gating to the time evolution output signal and Fourier transform.

3.1.25
transverse electric wave
TE wave
EM wave in which the electric field is perpendicular to the plane of incidence when the EM wave is incident to the specimen surface at an oblique angle

3.1.26
transverse electromagnetic wave
TEM wave
EM wave in which both the electric and magnetic fields are perpendicular to the direction of incidence when an EM wave is incident normally to the specimen surface

3.1.27
transverse magnetic wave
TM wave
EM wave in which the magnetic field is perpendicular to the plane of incidence when the EM wave is incident to the specimen surface at an oblique angle

3.2 Acronyms and symbols

The acronyms and symbols are shown in Table 1 and Table 2.

Table 1 – Acronyms

Acronyms	
CW	Continuous wave
EMA	Electromagnetic wave absorber
FFT	Fast Fourier transformation
IF	Intermediate frequency
NWA	Network analyzer
PTFE	Polytetrafruorethylene
SNA	Scalar network analyzer
TE	Transverse electric
TEM	Transverse electromagnetic
TM	Transverse magnetic
TRL	Thru-reflect-line
VNA	Vector network analyzer
VSWR	Voltage standing wave ratio

Table 2 – Symbols

Symbol	Meaning
A	A half size of the aperture of an ideal absorber wall (a half side of metal plate with squared shape (Annex A)
a	Longer side size at aperture of pyramidal horn antenna
b	Shorter side size at the aperture of a pyramidal horn antenna
c	Length of pyramidal horn antenna
$\mathrm{C}(x)$	Fresnel integral
D	Diameter of the aperture of a conical horn antenna
d_1	Distance from mirror image of transmit antenna to the aperture of ideal absorber wall
d_2	Distance from the aperture of an ideal absorber wall to receiving antenna
D_{m}	Effective maximum dimension of the antenna aperture
E_0	Electric field strength at the position of an ideal absorber（Annex A）
E_{r}	Receiving electric field strength in the case that an ideal absorber has a square-shaped aperture with size 2a（Annex A）
E_{s0}	Receiving electric field strength in the case that ideal absorber is not put（Annex A）
G_{d}	Directional gain of horn antenna
R	Distance from the aperture of horn antenna to the specimen
R_a	Receiving level in the case that the test specimen is put on the specimen holder (dB)
R_{m}	Receiving level in the case that the reference metal plate is put on the specimen holder（dB）
S_{11}	Reflection coefficient
S_{21}	Transmission coefficient
$S(x)$	Fresnel integral
V_a	Receiving voltage in the case that the test specimen is put on the specimen holder
V_{d}	Receiving voltage by direct wave from the transmitting and receiving antenna
V_{m}	Receiving voltage by the reflected wave from the metal plate with the same cross section and shape as the test specimen
V_{r}	Receiving voltage by the reflected wave except for the test specimen

Table 2 *(continued)*

Symbol	Meaning
V_s	Receiving voltage by the reflected wave only from the test specimen
β	Phase constant (=$2\pi/\lambda$)
Γ_a	Receiving level in the case that the electromagnetic absorber is put on the specimen holder (vector quantity)
Γ_m	Receiving level in the case that the reference metal plate is put on the specimen holder (vector quantity)
Γ_r	Receiving level in the case that the test specimen is not put on the specimen holder (vector quantity)
ε_r'	Real part of relative permittivity
θ	Incident angle of electromagnetic wave
λ	Wavelength of electromagnetic wave in free-space

4 Specimen

4.1 Specimen specification

It is recommended that the specimen have a flat surface and rigid structure having a dimension equal to or larger than 10 λ_l , where λ_l is the wavelength of the EM wave at the lowest frequency in the measurement frequency range. However, detailed specifications are given in each type of the three measurement methods described in Clauses 9, 10, and 11.

4.2 Reference metal plate

4.2.1 Material and thickness

Aluminium, copper, stainless steel or other metal, which has thickness of about 1 mm to 2 mm, is preferred.

4.2.2 Surface roughness

The surface roughness of a reference metal plate should be less than $\lambda_m/10$, although less than $\lambda_m/20$ is preferred, where λ_m is the wavelength that corresponds to maximum frequency in the measurement frequencies range. For example, if the maximum frequency is 300 GHz, then λ is 1 mm, and the preferable roughness becomes 0,05 mm.

4.2.3 Flatness

It is recommended that the flatness be less than 0,5 mm for a reference metal plate with size 1 m × 1 m.

4.2.4 Size and shape

The reference metal plate should have the same size and same projection shape normal to the specimen surface. However, it is desirable to use the size specified by each method in Clauses 9, 10, and 11. Care should be taken in selecting the size of the reference metal plate because the reflection and scattering characteristics may depend on its size due to the Fresnel refraction. The dependence of the reflection and scattering characteristics on the size in the case of the horn antenna method is illustrated in Annex A.

4.3 Reference specimen for calibration

The reference specimen for calibration should be silica-glass plate or sapphire single crystal (001) plate with uniform thickness and smooth surface roughness. Relative permittivity should