PUBLICLY AVAILABLE SPECIFICATION

IEC PAS 62431

Pre-Standard

First edition
2005-07

Measurement methods for reflectivity of electromagnetic wave absorbers in millimetre wave frequency

Reference number
IEC/PAS 62431:2005(E)

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

Consolidated editions

The IEC is now publishing consolidated versions of its publications. For example, edition numbers 1.0, 1.1 and 1.2 refer, respectively, to the base publication, the base publication incorporating amendment 1 and the base publication incorporating amendments 1 and 2.

Further information on IEC publications

The technical content of IEC publications is kept under constant review by the IEC, thus ensuring that the content reflects current technology. Information relating to this publication, including its validity, is available in the IEC Catalogue of publications (see below) in addition to new editions, amendments and corrigenda. Information on the subjects under consideration and work in progress undertaken by the technical committee which has prepared this publication, as well as the list of publications issued, is also available from the following:

- **IEC Web Site (www.iec.ch)**

- **Catalogue of IEC publications**

  The on-line catalogue on the IEC web site (www.iec.ch/searchpub) enables you to search by a variety of criteria including text searches, technical committees and date of publication. On-line information is also available on recently issued publications, withdrawn and replaced publications, as well as corrigenda.

- **IEC Just Published**

  This summary of recently issued publications (www.iec.ch/online_news/_justpub) is also available by email. Please contact the Customer Service Centre (see below) for further information.

- **Customer Service Centre**

  If you have any questions regarding this publication or need further assistance, please contact the Customer Service Centre:

Email: custserv@iec.ch
Tel: +41 22 919 02 11
Fax: +41 22 919 03 00

PUBLICLY AVAILABLE SPECIFICATION

IEC PAS 62431

Pre-Standard

First edition
2005-07

Measurement methods for reflectivity of electromagnetic wave absorbers in millimetre wave frequency

International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE X

For price, see current catalogue

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

A PAS is a technical specification not fulfilling the requirements for a standard but made available to the public.

IEC-PAS 62431 has been processed by subcommittee 46F: RF and microwave passive components, of IEC technical committee 46: Cables, wires, waveguides, r.f. connectors, r.f. and microwave passive components and accessories.

The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
46F/26/NP	46F/29/RVN

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned will transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of three years starting from 2005-07. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

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

1 Scope

This PAS specifies the measurement methods for the reflectivity of electromagnetic wave absorbers (EMA) for the normal incident, oblique incident and each polarized wave in the frequency range from 30 GHz to 300 GHz. In addition, these methods are also equally effective for the reflectivity measurement of other materials.

This PAS is applicable not only to those EMA which are widely used as the 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 indicated below.

Material:	Conductive material, dielectric material, magnetic material
Shape:	Planar, pyramidal-type, wedge-type, etc.
Layer structure:	Single layer, multi layers, and graded-index material

This PAS may give the measurement method of reflectivity applicable to various EMAs or materials. However, it may not be applicable to all EMAs.

This PAS may be supplemented with additional methods if necessary so that a future demand may be fulfilled.

The PAS specifies the measurement methods for the reflectivity of EMA in the millimetre-wave range:

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

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*

IEEE 1128, IEEE *Recommended Practice for EMA evaluation in the range from 30 MHz to 5 GHz*

3 Terms, definitions and acronyms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions of IEEE 1128, as well as the following apply.

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

3.1.2
dynamic range
difference in decibels between the receiving level from a reference metal plate and the receiving level measured when the metal plate is removed

3.1.3
directional gain
ratio of the radiated power density in a particular direction to the average power density that would be radiated in all directions

3.1.4
dielectric lens
electromagnetic wave lens that is composed of dielectric material, usually mounted in front of a pyramidal or conical horn

3.1.5
electromagnetic wave absorber
material ingredient which absorbs the electromagnetic wave energy and dissipates it thermally

3.1.6
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

3.1.7
Fraunhofer region
The region where the angular radiation pattern of an aperture antenna is nearly independent of the distance.

3.1.8
Fresnel region
region where the angular radiation pattern of an aperture antenna depends on the distance except for the extremely near region from the aperture

3.1.9
free-space method
measurement method that employs a single or a pair of horn antennas where the specimen and the antennas are put in free space

3.1.10
horn antenna
aperture antenna where impedance matching is taken gradually from the waveguide aperture to free space

3.1.11
normal incidence
incident electromagnetic wave striking normally to the specimen surface. The reflectivity in normal incidence is usually measured in the configuration where the incident angle of a transmit antenna and that of a receive antenna are within 0～5° with respect to the normal direction of the specimen surface

3.1.12
oblique incidence
incident electromagnetic wave striking to the specimen surface at an oblique angle. The reflectivity in oblique incidence is usually measured with a transmit and a receive antenna set up so that the incident and reflected angle of the EM wave may be equal

3.1.13
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 the front of a horn antenna

3.1.14
monostatic measurement
measurement where the incident and reflected waves follow the same direction which lie at an arbitrary angle with respect to normal to the specimen surface

3.1.15
bistatic measurement
measurement where the incident and reflection angle is equal

3.1.16
beam waist
portion at which the diameter of the focused beam becomes minimum when the electromagnetic wave radiated from a transmit antenna is converged using a dielectric lens

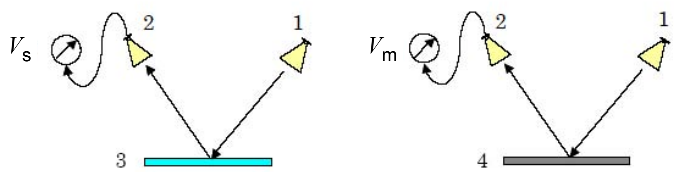
3.1.17
focal point
centre of beam waist when the electromagnetic waves are converged using a dielectric lens

3.1.18
focal distance
distance between the centre of the dielectric lens and the focal point

3.1.19
reflectivity
reflectivity is expressed by

$$\text{reflectivity} = 20\log_{10}\left|\frac{V_s}{V_m}\right| \text{ [dB]},$$

where V_s is the reflected EM wave voltage received by the receive antenna when the 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 as normal to specimen surface



Key
1 Tx antenna
2 Rx antenna
3 EMA
4 Metal plate

Figure 1 – Definition of reflectivity

3.1.20
reference metal plate
metal plate with the same shape and equal surface projected area as normal to the specimen

3.1.21
transverse electromagnetic wave
EM wave in which both the electric and magnetic fields are perpendicular to the plane of incidence when an EM wave is incident normally to the specimen surface

3.1.22
transverse electric 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

3.1.23
transverse magnetic 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

3.1.24
time-domain function
VNA generally has a function to transform the measured frequency domain data to time evolution data using Fourier transform because the VNA can measure both the amplitude and phase of EM wave. Therefore, the reflected wave only from the specimen can be extracted by applying a suitable time gating to the time evolution output signal and inverse Fourier transform

3.2 Acronyms

Acronyms	
EMA	Electromagnetic wave absorber
NWA	Network analyser
VNA	Vector network analyser
TEM	Transverse electromagnetic
TE	Transverse electric
TM	Transverse magnetic

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 15 λ where λ is the wavelength of the EM wave at the lowest frequency in the measurement frequency range. However, the detailed specifications are given in each type of the two measurement methods described below.

4.2 Reference metal plate

4.2.1 Material and thickness

Aluminium, copper, stainless steel etc., which has a thickness of 1 mm to 2 mm, is preferred.

4.2.2 Surface roughness

The surface roughness of a reference metal plate should be less than $\lambda/10$, although less than $\lambda/20$ is preferred, where λ is the wavelength that corresponds to the 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

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 described below. 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

A 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 be known in advance. When the dielectric material is selected, it is necessary to measure the reflectivity of the specimen without putting anything on the backward surface of the reference specimen. The reference specimen should be fixed by foamed plastics, which have a relative permittivity, of near to 1, and EM waves do not reflect as in free space. It is recommended that the accuracy of the measurement system be measured by comparing the measured reflectivity with the theoretical one. The reflectivity of a silica-glass plate or sapphire plate measured in the millimetre wave range is given in Annex B.

5 Specimen holder

A specimen holder may be different from any type of measurement method mentioned below. The specimen holder should possess functions of adjusting azimuth and elevation.

6 Measurement equipment

Correct usage of the measurement equipment is very important in order to obtain the exact results. The measurement of the reflectivity of EMA shall be performed using either a VNA or scalar network analyser. When there are discrepancies in the measured results, it is necessary to make calibration of the measurement system using a reference specimen. The necessary equipment should be selected according to the type of measurement methods used, as shown in below.

6.1 Network analyser

6.1.1 Vector network analyser

The VNA is recommended because it can measure both the amplitude and phase and time domain function.

6.1.2 Scalar network analyser

The scalar network analyser can only measure the amplitude, and does not have time-domain function, which is mainly used for relatively low accuracy measurement.

6.2 Antenna

6.2.1 Horn antenna

Both a commercial as well as an in-built horn antenna can be used for the reflectivity measurement of EMA except in special cases. However, The commercial horn antenna is recommended in order to obtain the required measurement accuracy, which has an accurate gain, VSWR, and size. The commercial coaxial-waveguide transducer is also recommended where the VSWR or sizes are verified in each frequency band. The specifications of some commercial horn antennas are shown in Annex C.

6.2.2 Lens antenna

Not only a dielectric lens antenna but also a metal-plate lens antenna or Luneberg lens antenna can be used for the reflectivity measurement of EMA in this PAS. Either a commercially available or an in-built product can also be applicable. However, the use of a commercial antenna, in which the antenna gain, VSWR, and sizes are specified, will be recommended in order to realize the required measurement accuracy. The specifications of commercial horn antennas and dielectric lenses are illustrated in Annex C.

6.3 Amplifier

An amplifier is generally used in order to get sufficient dynamic range of the measurement system. The warming-up of the amplifier is required, and the temperature should be kept as constant as possible because the total gain of the amplifier will vary due to the temperature drift as described in Clause 7.

7 Measurement condition

7.1 Temperature and environment

The measurement should be carried out in the atmosphere from 860 hPa to 1 060 hPa, and in the room from 5 °C to 35 °C, and relative humidity from 45 % to 85 %. If the operation temperature and humidity range of the measurement equipment are narrower than the above range, the specifications of the measurement equipment should be followed. It is desirable to control the measurement temperature within ±3 °C in order to suppress the influence of the temperature drift of measurement equipment to a minimum. The measurement temperature of the specimen should be selected to be 20 °C, 23 °C or 25 °C. In the case of high humidity, relative humidity should be maintained at either 50 % or 65 % in measurement.

7.2 Calibration temperature of measurement equipment

If the temperature at which measurement equipment is calibrated is within ±3 °C around the measurement temperature, measurement errors can be minimized. However, if the measurement temperature exceeds the range of ±3 °C, then it is recommended to carry out the calibration again.

7.3 Warming-up of measurement equipments

The warming-up time must be kept, typically 15-45 min, written in the specifications of the measurement equipment or systems. Moreover, the warming-up time should be taken to be longest in all of the measurement equipments.

7.4 Electromagnetic environment

When the EM wave power density in the measurement environment exceeds the public regulation, and when the EM environment is judged to be not so good, the measurement should be carried out in an anechoic room. When the directional gain of an antenna is large, however, an anechoic chamber may not necessarily be required.