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INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 1
AMENDEMENT 1

Ultrasonics – Hydrophones –
Part 2: Calibration for ultrasonic fields up to 40 MHz

Ultrasons – Hydrophones –
Partie 2: Etalonnage des champs ultrasoniques jusqu'à 40 MHz

IEC 62127-2:2007/A1:2013

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FOREWORD

This amendment has been prepared by IEC technical committee 87: Ultrasonics.

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

FDIS	Report on voting
87/519/FDIS	87/527/RVD

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

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability 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- withdrawn,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
- amended.

Replace throughout the document:
“non-linear” by “nonlinear”,
This replacement applies to the English text only.

Replace throughout the document:
“non-linearity” by “nonlinearity”
This replacement applies to the English text only.

Replace throughout the document:
“non-linearities” by “nonlinearities”
This replacement applies to the English text only.

Replace throughout the document:
“non-linearly” by “nonlinearly”
This replacement applies to the English text only.

2 Normative references

Replace the references to IEC 60050-801:1994, IEC 61161:2006, IEC 61828:2006 and IEC 62127-1, *by the following new references:*

IEC 60050-801, *International Electrotechnical Vocabulary – Chapter 801: Acoustics and electroacoustics*

IEC 61161, *Ultrasonics – Power measurement – Radiation force balances and performance requirements*

IEC 61828, *Ultrasonics – Focusing transducers – Definitions and measurement methods for the transmitted fields*

IEC 62127-1:2007, *Ultrasonics - Hydrophones - Part 1: Measurement and characterization of medical ultrasonic fields up to 40 MHz*
Amendment 1:2013

3 Terms, definitions and symbols

3.9
effective radius of a non-focused ultrasonic transducer
Replace the term by **effective radius of a non-focusing ultrasonic transducer**

Replace the term in the Note by **effective radius of a non-focusing ultrasonic transducer**

3.14
external transducer aperture

*Replace, in Note 1, "*Figure 2*" by "*Figure 1*".*

3.15
far field

Replace the existing text of the definition (not including Note 1 and Note 2) by the following:

region of the field where $z>z_T$ aligned along the **beam axis** for planar non-focusing transducers.

Add the following new Note 3:

NOTE 3 If the shape of the transducer aperture produces several **transition distance**s, the one furthest from the transducer shall be used.

[SOURCE: IEC 62127-1:2007/Amendment 1:2013, definition 3.28]

3.23
instantaneous intensity

Replace the existing text of Note 1 by the following:

NOTE 1 **Instantaneous intensity** is the product of **instantaneous acoustic pressure** and particle velocity. It is difficult to measure intensity in the ultrasound frequency range. For the measurement purposes referred to in this International Standard and under conditions of sufficient distance from the **external transducer aperture** (at least one transducer diameter, or an equivalent transducer dimension in the case of a non-circular transducer) the **instantaneous intensity** can be approximated by the **derived instantaneous intensity.**

Replace the existing text of Note 2 by the following:

Instantaneous intensity is expressed in watts per square metre (W/m^2)

Add the following new definitions:

3.26
derived instantaneous intensity
approximation of the **instantaneous intensity**

For the measurement purposes referred to in this International Standard, and under conditions of sufficient distance from the transducer (at least one transducer diameter, or an equivalent transducer dimension in the case of a non-circular transducer) the **derived instantaneous intensity** is determined by

$$I(t) = \frac{p(t)^2}{\rho c} \qquad (1)$$

where:

p(*t*) is the **instantaneous acoustic pressure**;

ρ is the density of the medium;

c is the speed of sound in the medium.

NOTE 1 For measurement purposes referred to in this International Standard, the **derived instantaneous intensity** is an approximation of the **instantaneous intensity**.

NOTE 2 Increased uncertainty should be taken into account for measurements very close to the transducer.

NOTE 3 **Derived instantaneous intensity** is expressed in watts per square metre (W/m^2).

[SOURCE: IEC 62127-1:2007/ Amendment 1:2013, definition 3.78]

3.27
effective wavelength
λ
longitudinal speed of sound in the propagation medium divided by the **arithmetic-mean working frequency**

NOTE **Effective wavelength** is expressed in metres (m).

[SOURCE:IEC 61828:2001, definition 4.2.24].

3.28
longitudinal plane
plane defined by the **beam axis** and a specified orthogonal axis

NOTE See Figure 1 in IEC 62127-1.

[SOURCE: IEC 62127-1:2007, definition 3.35].

3.29
source aperture plane
closest possible measurement plane to the **external transducer aperture**, that is perpendicular to the **beam axis**

[SOURCE:IEC 61828:2001, definition 4.2.67].

3.30
source aperture width
L_{SA}
in a specified **longitudinal plane**, the greatest –20 dB **beamwidth** along the line of intersection between the designated **longitudinal plane** and the **source aperture plane**

NOTE 1 See Figure 2 in IEC 61828 2001.

NOTE 2 **Source aperture width** is expressed in metres (m).

[SOURCE:IEC 61828, definition 4.2.68].

3.31
transducer aperture width
$\boldsymbol{L_{TA}}$
full width of the transducer aperture along a specified axis orthogonal to the beam axis of the unsteered beam at the centre of the transducer

NOTE 1 See Figure 4 in IEC 62127-1 .

NOTE 2 **Transducer aperture width** is expressed in metres (m).

[SOURCE:IEC 62127-1:2007/ Amendment 1:2013, definition 3.87].

3.32
transition distance
$\boldsymbol{z_T}$
for a given **longitudinal plane**, the **transition distance** is defined based on the transducer design (when known) or from measurement:

a) from design: the **transition distance** is the equivalent area of the ultrasonic **transducer aperture width** divided by π times the **effective wavelength**, λ;

b) for measurements, the **transition distance** is the equivalent area of the **source aperture** width divided by π times the **effective wavelength**.

NOTE 1 Using method a), an unapodized **ultrasonic transducer** with circular symmetry about the **beam axis,** the equivalent area is πa^2, where a is the radius. Therefore the **transition distance** is $z_T = a^2/\lambda$. For the first example of a square **ultrasonic transducer,** the equivalent area is $(L_{TA})^2$, where L_{TA} is the **transducer aperture width** in the **longitudinal plane**. Therefore, the **transition distance** for both orthogonal **longitudinal planes** containing the sides or **transducer aperture widths,** is $z_T = (L_{TA})^2 /(\pi\lambda)$. For the second example, for a rectangular **ultrasonic transducer** with **transducer aperture widths** L_{TA1} and L_{TA2}, the equivalent area for the first linear transducer aperture width for the purpose of calculating the **transition distance** for the associated **longitudinal plane** is $(L_{TA1})^2$, where L_{TA1} is the **transducer aperture width** in this **longitudinal plane**. Therefore, the **transition distance** for this plane is $z_{T1} = (L_{TA1})^2 /(\pi\lambda)$. For the orthogonal **longitudinal plane** that contains the other **transducer aperture width**, L_{TA2}, the equivalent area for the other for the purpose of calculating the transition distance for the associated **longitudinal plane** is $(L_{TA2})^2$, where L_{TA2} is the **transducer aperture width** in this **longitudinal plane**. Therefore, the **transition distance** for this plane is $z_{T2} = (L_{TA2})^2 /(\pi\lambda)$.

NOTE 2 Using method b) for measurements in a longitudinal plane, the source aperture width, L_{SA}, in the same plane is used in $z_T = (L_{SA})^2 /(\pi\lambda)$.

NOTE 3 **Transition distance** is expressed in metre (m).

[SOURCE IEC 61828:2001, definition 4.2.75, modified: There is significant difference in the layout of the definition]

4 List of symbols

Replace:

a_t **effective radius of a non-focused ultrasonic transducer**

by

a_t **effective radius of a non-focusing ultrasonic transducer**

Add the following new symbols:

L_{TA} **transducer aperture width**

L_{SA} **source aperture width**

z_T **transition distance**

5 Overview of calibration procedures

5.3 Reporting of results

Add, after the sixth bullet point ("in situations where the mounting arrangement…") the following new Note 5 and renumber existing Notes 5 and 6 accordingly:

NOTE 5 Care should be taken in designing the **hydrophone** mount at low frequencies (below 200 kHz) where the acoustic wavelengths are sufficiently large that the use of long-bursts may lead to the direct acoustic signal being contaminated by reflections from the mount. The importance of the effect may be investigated through varying the burst length and observing the influence of reflections on the **hydrophone** signal. Acoustic absorbers may be useful in suppressing these reflections. **Hydrophone** sensitivity may also be affected by the way the **hydrophone** is clamped, and again this may be evaluated by systematically investigating the various configurations.

6 Generic requirements of a hydrophone calibration system

6.1 Mechanical positioning

6.1.2 Accuracy of the axial hydrophone position

Add, after Note 1, the following new Note 2 and renumber existing Notes 3 and 4 accordingly.:

NOTE 2 The distance of the **hydrophone** from the transducer can be estimated from a knowledge of the time elapsed between the electrical excitation applied to the transducer and the arrival time of the acoustic wave at the **hydrophone,** through a knowledge of the speed of sound in water at that particular temperature.

6.1.3 Accuracy of the lateral hydrophone position

Replace the existing first sentence of the subclause by the following:

The variation of the **hydrophone** output voltage should be checked when the lateral **hydrophone** position is changed to ensure that the signal is maximized.

6.3 Hydrophone size

Number the existing note as Note 1 and add the following new Note 2:

NOTE 2 Guidance in assessing the influence of spatial-averaging on calibrations may be found in IEC 62127-1 and Annex J.

6.4 Measurement vessel and water properties

Replace the existing first paragraph with the following:

The test tank shall be sufficiently large to allow the establishment of free field conditions at the lowest frequency of interest. It should also be large enough to allow the transducer-**hydrophone** separation to be varied to a degree consistent with the requirements of the applied calibration technique.

7.2 Earthing

Add the following new note:

NOTE This condition may be relaxed when a tone burst is used such that the acoustic signal arrives at the **hydrophone** after the electrical excitation is completed.

7.3.5 Cross-talk (radio-frequency *rf* pick-up) and acoustic interference

Add, after the second paragraph, the following new Note 1 and renumber the existing note as Note 2:

NOTE 1 In these situations, cross-talk will contaminate the direct acoustic signal. The effect can be evaluated through varying the tone-burst length and observing any consequent changes in the hydrophone waveform using an oscilloscope.

8.2 Wetting

Replace the existing text by the following:

The user shall ensure that the **hydrophone** is wetted properly and that all air bubbles are removed from the **hydrophone** and faces taking active part in the calibration. After measurements are completed, the active faces shall again be inspected, and the measurements shall be discarded if any air bubbles are found.

9 Free field reciprocity calibration

9.4 Two-transducer reciprocity calibration method

Add the following new note:

NOTE Within this standard, information on this calibration technique is also presented in Annex K and is provided for information purposes.

9.4.2 Procedure

Replace the existing text by the following:

In the configuration, the auxiliary transducer is calibrated and then the reflector is removed to calibrate the **hydrophone**.

When calibrating the auxiliary transducer, rotate the reflector through an angle of approximately 10° about an axis parallel to its surface and perpendicular to the line joining the acoustic centres of the **hydrophones** and auxiliary transducer.

NOTE This method has been improved through a coaxial configuration of the **hydrophone** and the auxiliary transducer with the reflector in the middle of them. This can avoid the error caused by rotation of the reflector and make the alignment of the **hydrophone** and the auxiliary transducer easier, and the error can be reduced to about 0,5 dB.

10.5.3 Measurement conditions

*Replace, in the Note, the terms "***effective radius of a non-focused ultrasonic transducer***" by "***effective radius of a non-focusing ultrasonic transducer***".*

12.5.1 Measurement (Type 1): determination of the directional response of a hydrophone

Replace the existing Note 4 by the following:

NOTE 4 The **effective hydrophone radius** is important for the assessment of spatial averaging effects (see Annex J and IEC 62127-1). The **effective hydrophone radius** might be frequency dependent for some types of

hydrophone and for any particular **hydrophone** might be dependent on the chosen axis. Further information on the **effective hydrophone radius** may be found in IEC 62127-3.

Annex D – Absolute calibration of hydrophones using the planar scanning technique

D.3.6 Noise

*Replace, in the first sentence of the first paragraph, the term "***beam axis centre***" by "***beam axis***".*

Annex E – Properties of water

Add, at the end of the existing text, the following new sentence:

Procedures to prepare degassed water are given in IEC/TS 62781.

Annex F – The absolute calibration of hydrophones by optical interferometry up to 40 MHz

F.2.3.1.4 Multipass effects in the foil

*Replace, in the last sentence of the subclause "*transmission factor, *T*,*" by "*transmission factor, *TF*,".

Annex G – Waveform concepts

G.5.2 Influence of edge-waves

*Replace, in the first sentence, "*transducer, x,*" by "*transducer, z,".

Annex I – Determination of the phase response of hydrophones

I.1 Overview

Add, at the end of the penultimate sentence in the first paragraph, the following bibliographic references [76], [77], [78]

Add, after Annex J, the following new annex:

Annex K
(informative)

Two-transducer reciprocity calibration method

K.1 Overview

A number of techniques are described in technical literature addressing the absolute determination of acoustic field parameters. The absolute determination of acoustic pressure amplitude at a single point within an acoustic field may be accomplished through the use of a calibrated hydrophone. The choice of technique used to calibrate the hydrophone may be made in terms of the resultant accuracy and convenience of applying the method. For example, whilst the optical interferometry described in Annex F represents a direct primary-standard method where the lowest calibration uncertainties can be achieved, it is highly demanding in terms of the facility requirements and it may be difficult to establish. Of the other hydrophone calibration methods, the two which have found most favor are reciprocity and planar scanning (see Annex D), the latter involving the measurement of total power in combination with the acoustic beam profile measured using a hydrophone.

The reciprocity technique involves measurement of the effect of the field on a second transducer (for the two-transducer method), or even the transducer generating the acoustic field (for the self-reciprocity method). The technique requires a relatively simple experimental facility compared to the two alternative methods: optical interferometry and planar scanning, and does not involve complex measurement procedures. It can therefore be established in any laboratory equipped for routine ultrasonic measurements. All of the measurements involved are electrical and the technique therefore can be made absolute, if indirect, as it does not involve the realization of the acoustic pascal. Nevertheless, electrical and acoustical corrections must be applied to the data, and the analysis of the results is rather complicated.

The now obsolete standard, IEC 60866, 1987, described detailed procedures to be followed in order to perform reciprocity calibration. For the reasons described above, it is considered valuable to include a virtual copy of the IEC 60866 descriptions within the present standard.

K.2 Additional terms, definitions and symbols

For the purpose of this annex, the following terms and definitions apply.

K.2.1
reversible transducer
transducer capable of acting as a projector as well as a **hydrophone**

[SOURCE: IEC 60565:2006, definition 3.26]

K.2.2
reciprocal transducer
linear, passive and reversible transducer

[SOURCE: IEC 60565:2006, definition 3.24]

K.2.3
open-circuit voltage at hydrophone
U
voltage appearing at the electrical terminals of a **hydrophone** when no current passes through the terminals

NOTE **Open-circuit voltage at hydrophone** is expressed in volt (V).

[SOURCE:IEC 60565:2006, definition 3.19]

K.2.4
free-field sensitivity of a hydrophone
M
ratio of the open circuit voltage of the **hydrophone** to the sound pressure in the undisturbed free field in the position of the **reference centre** of the **hydrophone** if the **hydrophone** were removed

NOTE 1 The pressure is sinusoidal.

NOTE 2 The term 'response' is sometimes used instead of 'sensitivity'.

NOTE 3 **Free-field sensitivity of a hydrophone** is expressed in volt per pascal (V/Pa).

[SOURCE: IEC 60565:2006, definition 3.15]

K.2.5
transmitting response to current of a projector
S
at a given frequency, the ratio of the acoustic pressure in the sound wave, at a point to be specified, in the absence of interference effects, to the current flowing through the electrical terminals of a projector

NOTE **Transmitting response to current of a projector** is expressed in pascal per ampere (Pa/A).

K.2.6
reciprocity coefficient
J
for any system in which a reciprocal transducer acts as a projector and receiver, the ratio of the free-field voltage sensitivity of the transducer, *M*, to its transmitting response to current, *S; w*here the transmitted sound waves approximate plane waves, the reciprocity coefficient approaches $2A/\rho c$ and is called the plane wave reciprocity coefficient

NOTE 1 The plane wave reciprocity coefficient applies to plane wave propagation, as realized in the far field of a transducer, but pure far field conditions are not used in the procedure described in K.5.6. To cope with this, a correction factor is described in K.4.4 which includes an allowance for deviations from plane wave conditions.

NOTE 2 **Reciprocity coefficient** is expressed in watt per squared pascal (W/Pa^2)

K.2.7
end-of-cable leakage resistance
$\boldsymbol{R_L}$
the ratio of the voltage across the electrical terminals at the end of the **hydrophone** cable to the direct current flowing through these terminals

NOTE 1 The value of the voltage used during the determination of the R_L should be stated.

NOTE 2 **End-of-cable leakage resistance** is expressed in ohm (Ω)

K.2.8
mechanical Q of hydrophone element
the ratio of the resonance frequency to the bandwidth between the two frequencies at which the motional impedance of the **hydrophone** is $1/\sqrt{2}$ times that at resonance

K.3 List of symbols used in this annex

A_1 Effective area of auxiliary transducer

a Effective radius of the **hydrophone**

a_1	Effective radius of auxiliary transducer
a_u	Factor by which the reference voltage U_{ref} must be reduced to make it equal to voltage U
a_{u1}	Factor by which the reference voltage U_{ref} must be reduced to make it equal to voltage U_1
a_{I1}	Factor by which the reference voltage U_{ref} must be reduced in order to drive a current I_1 through the impedance R_0
c	Speed of sound in a medium (usually water)
d	Distance between **hydrophone** and reflector
d_1	Distance between auxiliary transducer and reflector
G_1	Correction factor for diffraction loss with auxiliary transducer alone
G_2	Correction factor for diffraction loss with auxiliary transducer and **hydrophone**
G_c	Correction factor combining G_1 and G_2, applicable only under certain measurement conditions
I_1	Current through auxiliary transducer
I_k	Current through short circuit introduced in place of the auxiliary transducer
J	Reciprocity coefficient
J_p	{ = 2 $A/\rho c$ } Reciprocity coefficient for plane waves
k_{u1}	Correction to open-circuit voltage for the auxiliary transducer
k_u	Correction to open-circuit voltage at a **hydrophone**
M	Free-field sensitivity of a **hydrophone**
M^*	Apparent free-field sensitivity of a **hydrophone**, assuming ideal plane wave measurement conditions
N	Near field distance
p	Sound pressure
p_1	Sound pressure in plane wave omitted by auxiliary transducer
R_0	Impedance of standard load equal to the characteristic impedance of the precision attenuator
R_L	End-of-cable leakage resistance of **hydrophone**
r	Amplitude reflection coefficient for the reflector/water interface
s	{ = $(d_1 + d)\ \lambda/a_1^2$} Normalized distance from auxiliary transducer to **hydrophone**
S	Transmitting response to current of a projector
S_1	Transmitting response to current of auxiliary transducer
S_1^*	Apparent transmitting response to current of auxiliary transducer, assuming ideal plane wave measurement conditions
U	Open-circuit voltage at a **hydrophone**
U_1	Open-circuit voltage for auxiliary transducer
U_{ref}	Reference voltage
v	Velocity of the radiating surface of the transducer
z	Distance along the acoustic axis from the transducer
α	Amplitude attenuation coefficient of plane waves in a medium (usually water)
λ	Ultrasonic wavelength
ρ	(mass) Density of the measurement liquid (water)

K.4 Principle of the two-transducer reciprocity method

K.4.1 General

The recommended calibration procedure is based on the principles presented in K.4.2 to K.4.4.

K.4.2 Transmitting current response by self-reciprocity

A plane, reciprocal transducer (parameters relating to which will be identified by the suffix 1) is first calibrated by the self-reciprocity method (see K.9). Its apparent transmitting current response assuming ideal plane wave measurement conditions, S_1^*, is determined by measuring the current, I_1 , and the received signal voltage, U_1 , by means of the following relationship (Equation K.20):

$$S_1^* = \frac{p_1}{I_1} = \left(\frac{U_1}{I_1 J_p}\right)^{1/2} \qquad (K.1)$$

and

$$J_p = \frac{2\,A_1}{\rho c} \qquad (K.2)$$

where:

p_1 is the acoustic pressure in the plane wave emitted by transducer 1;

J_p is the reciprocity coefficient for plane waves;

A_1 is the effective area of the surface of transducer 1;

ρ is the density of the propagation medium (water);

c is the speed of sound in the propagation medium.

The acoustic pressure in the plane wave field transmitted by transducer 1 is then known as a function of the current.

K.4.3 Free-field voltage sensitivity by substitution

The **hydrophone** to be calibrated is immersed in the known sound field generated by transducer 1, and its output open-circuit voltage U determined. The apparent free-field voltage sensitivity, assuming ideal plane wave measurement conditions, M^*, is then given by:

$$M^* = \frac{U}{p_1} = \frac{U}{I_1}\left(\frac{I_1 J_p}{U_1}\right)^{1/2} \qquad (K.3)$$

K.4.4 Correction for non-plane wave conditions

It is not generally possible to realize either plane (or spherical) wave reciprocity conditions at the ultrasonic frequencies being considered here, because of the size of available, practical transducers compared with the wavelengths of the acoustic waves, and because of the relatively high acoustic absorption in water at these frequencies. In practice, an intermediate condition is used and allowance made for the frequency-dependent changes, such as diffraction and attenuation, which affect the acoustic wave during its propagation between projector and receiver. This allowance takes the form of a correction factor, k, applied during the calculation of the calibration results, where $M = M^{*}k$. The correction factor is based largely on the theoretical model of the pressure distribution in the field emitted by a plane, circular piston-like source, in which the velocity at any time is identical at all points on the radiating surface (see Clause K.11).

NOTE The theory of the two-transducer reciprocity method has been described in detail in reference [1] in Clause K.12.

K.5 Calibration measurement conditions

K.5.1 Overall experimental arrangement

Figure K.1, illustrates the experimental arrangement required for this method of calibration, and Figure K.2 shows the associated electrical circuits in their simplest form. The auxiliary transducer 1 radiates repetitive tone bursts of between 10 and 20 cycles into a water tank, where they are reflected by a thick stainless steel reflector. For the self-reciprocity calibration of the auxiliary transducer, the transducer is adjusted to a position in which the axis of the emitted ultrasonic beam is perpendicular to the reflecting surface; and for the second stage, the calibration of the **hydrophone**, the reflector is inclined so as to bring the **hydrophone** into the centre of the reflected acoustic field. The transducer and **hydrophone** should be arranged so that the angle of reflection used in the second stage is less than 10° to avoid significant departure in the value of the reflection coefficient from that at normal incidence.

K.5.2 The auxiliary transducer

The auxiliary transducer should have a plane, circular active face of diameter at least ten times the wavelength of sound in water at the frequency for which the transducer will be used, and should satisfy the conditions laid down in K.5.4 as to its suitability for use in reciprocity calibration procedures. Furthermore, the transducer should be chosen for its ability to radiate a field which conforms closely to that predicted theoretically for a plane, piston-like source.

NOTE As a guide to the selection of suitable auxiliary transducers, it is recommended that experimentally determined value of effective radius, a_1 (see K.5.3), should not differ from the true, physical radius of the active element of any chosen transducer by more than +2 % to –5 %.

Although one auxiliary transducer may be capable of satisfactory operation over a limited range of frequencies, a set of transducers will in general be required to cover the full calibration bandwidth.

K.5.3 The effective radius of the auxiliary transducer

The effective radius of the auxiliary transducer, a_1, is the radius of the equivalent piston-like source for which the spatial distribution of acoustic pressure amplitude in the far field most closely resembles that from the transducer itself. The effective radius is determined from a plot of acoustic pressure amplitude as a function of position along the beam axis, obtained by means of a **hydrophone** (details of the experimental method recommended for the determination of the effective radius are covered in K.10.1).

K.5.4 Checking the suitability of a transducer for use in reciprocity procedures

In practice, it is sufficient to check the applicability of particular transducers to reciprocity calibration procedures as follows. The transducers are checked in pairs, one being used as a projector and the other as a receiver. A comparison is made between the ratios of the open-circuit output voltage of the receiver to the input current of the projector when the functions of the projector and receiver are interchanged without changing their positions. These two values should not differ by more than 10 %. If the difference is larger, at least one of the