
Method (precision) for free-field calibration of one-inch standard condenser microphones by the reciprocity technique

Méthode de précision pour l'étalonnage en champ libre des microphones étalons
à condensateur d'un pouce par la technique de la réciprocité

Präzisionsverfahren für die Freifeldeichung von Einzell-Eichkondensatormikrofonen
nach der Reziprozitätstechnik

National foreword

This British Standard has been prepared under the direction of the Electronic Equipment Standards Committee and is identical with IEC Publication 486 : 1974 'Precision method for free-field calibration of one-inch standard condenser microphones by the reciprocity technique'.

Terminology and conventions. The text of the international standard has been approved as suitable for publication, without deviation, as a British Standard. Some terminology and certain conventions are not identical with those used in British Standards; attention is especially drawn to the following.

Wherever the word 'recommendation' appears, referring to this standard, it should be interpreted as 'British Standard'.

Where in 3.1 the words 'IEC reference configuration' appear, they should be interpreted as 'British Standard reference configuration'.

NOTE. Textual errors. When adopting the text of the international standard, the irregularities listed below were noticed. They have been reported to the International Electrotechnical Commission in a proposal to amend the text of the international standard.

Note to 4.6.1	In three instances the symbol ' Δ ', as printed (upright) in the standard, should be read as if printed italic.
6.1 and 6.7	In a total of four instances the symbol 'r', as printed (upright) in the standard, should be read as if printed italic.

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British Standard

Method (precision) for free-field calibration of one-inch standard condenser microphones by the reciprocity technique

1. Scope

This recommendation describes a method for the free-field reciprocity calibration of one-inch condenser microphone capsules used as laboratory standards.

2. Object

The object of this recommendation is to specify methods of measuring certain characteristics of standard condenser microphones with high accuracy, so that discussions between testing authorities may be based on clearly expressed and reproducible results. Although the free-field calibration of condenser microphones is a problem of a general nature, this recommendation (as regards specific figures, measures and numbers) is restricted to microphones commonly known as one-inch condenser microphones, having a nominal outer diameter of 0.936 in = 23.77 mm.

Note. — The method is described in detail so that the overall precision obtained in any calibration can be estimated.

3. Explanation of terms

3.1 Open-circuit voltage

The open-circuit voltage of a microphone at a given frequency is the voltage appearing at its electrical terminals when the microphone is electrically unloaded.

However, owing to the capacitive nature of the cartridge, the voltage at the electrical terminals will depend on the electrical load caused by the mechanical attachment to the microphone. For the purpose of this recommendation, the open-circuit voltage is the voltage appearing at the electrical terminals of the cartridge as measured by the insert voltage technique when the microphone is attached to a ground shield having the IEC reference configuration, but is otherwise electrically unloaded (see Sub-clauses 6.2. and 6.3).

Unit: volt, V.

3.2 Free-field sensitivity of a microphone

The free-field sensitivity M_f of a microphone at a given frequency and for a sinusoidal waveform is the ratio of the open-circuit voltage of the microphone to the sound pressure that existed at the position of the acoustic centre of the microphone prior to the introduction of the microphone into the sound field. The sound field shall be a plane progressive wave under free-field conditions, and the angle of incidence with respect to the principal axis of the microphone shall be zero unless otherwise specified. This ratio is a complex quantity, but when the phase information is of no interest, the free-field sensitivity may denote its modulus only.

Unit: volt per pascal, V/Pa.

Notes 1. — The subscript U is omitted from the preferred symbol M_{fU} since the sensitivity is expressed in terms of the open-circuit voltage throughout this recommendation.

2. — It should be noted that the term “free-field response” is sometimes used instead of “free-field sensitivity”.

3. — At frequencies sufficiently low for the disturbance of the sound field by the microphone to be negligible, the free-field sensitivity approaches the pressure sensitivity.

3.2.1 *Free-field sensitivity level of a microphone*

The free-field sensitivity level relative to a reference sensitivity M_r is defined as $20 \log_{10} \left| \frac{M_f}{M_r} \right|$ where M_r is 1 V/Pa.

Unit: decibel, dB.

3.2.2 *Free-field sensitivity phase angle of a microphone*

The free-field sensitivity phase angle of a microphone at a given frequency is the phase angle between the open-circuit voltage and the sound pressure at the position of the acoustic centre of the microphone prior to the introduction of the microphone into the sound field.

Unit: degree or radian.

3.3 *Electrical impedance of a microphone*

The electrical impedance of a microphone at a given frequency is the complex ratio of the voltage applied across its electrical terminals to the resulting current.

Unit: ohm, Ω .

Note. — This impedance is a function of the acoustic load on the diaphragm and of the ground-shield configuration.

3.4 *Acoustic impedance of a microphone*

For the purpose of this recommendation, the acoustic impedance of a microphone at a given frequency is the complex ratio of the sound pressure to the volume velocity of the diaphragm, the sound pressure being uniformly applied to the diaphragm and the electrical terminals being unloaded.

Unit: pascal second per cubic metre, Pa.s/m³.

3.5 *Acoustic centre of a microphone*

For a sound-emitting transducer, at a given frequency and at a specified direction and distance, the acoustic centre is the point from which the approximately spherical wavefronts, as observed in a small region around the observation point, appear to diverge.

Note. — The acoustic centre of a reciprocal transducer when used as a receiver is coincident with the acoustic centre when used as a transmitter.

3.6 *Principal axis of a microphone*

The principal axis of a microphone is the line through the centre of, and perpendicular to, the diaphragm of the microphone.

3.7 *Free-field conditions*

Free-field conditions prevail when a sound wave can propagate freely without disturbance of any kind.

3.8 *Reciprocal microphone*

Consider a linear, passive microphone.

At a given single frequency, let:

p be the complex representation of the sound pressure at the diaphragm

U be the complex representation of the voltage at the electrical terminals of the microphone

q be the complex representation of the volume velocity of the diaphragm

I be the complex representation of the current through the electrical terminals of the microphone

The equations of the microphone can then be written as:

$$\begin{cases} Z_{11} I + Z_{12} q = U \\ Z_{21} I + Z_{22} q = p \end{cases} \quad (1)$$

where:

Z_{11} is the electrical impedance of the microphone when the diaphragm is blocked

Z_{22} is the acoustic impedance of the microphone when the electrical terminals are unloaded

The microphone is said to be reciprocal if the transduction coefficients Z_{12} and Z_{21} are such that $Z_{12} = \pm Z_{21}$.

When sound pressure p is not uniform over the surface of the diaphragm, as will be the case at high frequencies when the microphone is located in a plane progressive wave, the location of the acoustical terminals is not obvious. In this case, a special interpretation of p in equation (1) will be necessary (see Sub-clause 4.3).

For a given orientation of any reciprocal transducer, an equivalent point-transducer exists which simulates the receiving as well as the transmitting characteristics of the real transducer at remote points. This equivalent point-transducer is located at the position of the acoustic centre of the real transducer for that particular direction (see Sub-clause 3.5).

4. Principles of a free-field reciprocity calibration

4.1 General

A reciprocity calibration of microphones may be carried out either by means of three microphones, two of which must be reciprocal, or by means of an auxiliary sound source and two microphones, one of which must be reciprocal.

4.1.1 General principles of the method using three microphones

Let two of the microphones be located under free-field conditions. Using one of them as a sound source and the other as a sound receiver, the ratio of the output open-circuit voltage of the receiver to the input current of the transmitter is measured. When the acoustic coupling properties of the system are known, the product of the free-field sensitivities of the two coupled microphones can be determined (see Sub-clause 4.4). Using pairwise combinations of the microphones (a), (b) and (c), three independent products are available, from which an expression for the free-field sensitivity of each of the three microphones can be derived.

4.1.2 General principles of the method using two microphones and an auxiliary sound source

First let the two microphones be coupled acoustically under free-field conditions and the product of the free-field sensitivities of the two coupled microphones be determined (see Sub-clause 4.1.1). The ratio of the two free-field sensitivities can be determined by presenting the two microphones sequentially to the same sound pressure set up by the auxiliary sound source under free-field conditions. Thus, from the product and the ratio of the free-field sensitivities of the two microphones, an expression for the free-field sensitivity of each of the microphones can be derived.

4.2 Acoustic conditions

The definition of the free-field sensitivity of a microphone refers to the sound pressure in an undisturbed plane progressive wave. In the far field of a sound source located under free-field conditions, spherical waves are generated which, at a sufficient distance from the source, approximate to plane progressive waves in a limited region. Thus, the distance between the receiver microphone and the transmitter microphone shall be great enough to ensure an approximately plane wave in a suitable region around the receiver microphone (see Sub-clause 5.2.7).

On the other hand, the influence of disturbing surroundings increases as the distance between the two microphones is increased. Therefore, the metrological conditions should be carefully chosen, so that the requirements of Sub-clause 5.2.8 are satisfied.