

ANSI/ASA S1.20-2012
(Revision of ANSI S1.20-1988 (R2003))

AMERICAN NATIONAL STANDARD

**Procedures for Calibration of Underwater
Electroacoustic Transducers**

ANSI/ASA S1.20-2012

Accredited Standards Committee S1, Acoustics

Standards Secretariat
Acoustical Society of America
35 Pinelawn Road, Suite 114 E
Melville, NY 11747-3177

The American National Standards Institute, Inc. (ANSI) is the national coordinator of voluntary standards development and the clearinghouse in the U.S.A. for information on national and international standards.

The Acoustical Society of America (ASA) is an organization of scientists and engineers formed in 1929 to increase and diffuse the knowledge of acoustics and to promote its practical applications.



ANSI/ASA S1.20-2012
(Revision of ANSI S1.20-1988 (R 2003))

AMERICAN NATIONAL STANDARD

**Procedures for Calibration of Underwater
Electroacoustic Transducers**

Secretariat:

Acoustical Society of America

Approved February 17, 2012 by:

American National Standards Institute, Inc.

Abstract

This standard establishes measurement procedures for calibrating underwater electroacoustic transducers. It is a revision of American National Standard S1.20-1988 (R2003). Both primary and secondary calibration procedures are specified for frequencies from a few hertz to a few megahertz. Procedures are specified for determining the measurable characteristics of free-field receive voltage sensitivity, transmitting response, directional response, voltage coupling loss, impedance, and equivalent noise pressure. Measurement uncertainty analysis is introduced for these measurement types, with identification of common error sources. Equations are given for the following derived characteristics: beam pattern, directivity factor and index, equivalent two-way beam width, acoustic power output and level, electrical power input, transmitting efficiency, open-circuit effective bandwidth, and quality factor. Annexes have been included to address: A) free-field calibration in a laboratory tank, B) medium correction factors, C) measurement of sensitivity and response— infrasonic and low audio-frequency range, D) phase of free-field voltage sensitivity via reciprocity method, E) nonlinear effects including cavitation, and F) standard-target method for calibrating active sonars.

AMERICAN NATIONAL STANDARDS ON ACOUSTICS

The Acoustical Society of America (ASA) provides the Secretariat for Accredited Standards Committees S1 on Acoustics, S2 on Mechanical Vibration and Shock, S3 on Bioacoustics, S3/SC 1 on Animal Bioacoustics, and S12 on Noise. These committees have wide representation from the technical community (manufacturers, consumers, trade associations, organizations with a general interest, and government representatives). The standards are published by the Acoustical Society of America as American National Standards after approval by their respective Standards Committees and the American National Standards Institute (ANSI).

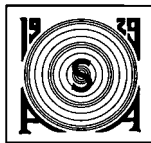
These standards are developed and published as a public service to provide standards useful to the public, industry, and consumers, and to Federal, State, and local governments.

Each of the Accredited Standards Committees (operating in accordance with procedures approved by ANSI) is responsible for developing, voting upon, and maintaining or revising its own Standards. The ASA Standards Secretariat administers Committee organization and activity and provides liaison between the Accredited Standards Committees and ANSI. After the Standards have been produced and adopted by the Accredited Standards Committees, and approved as American National Standards by ANSI, the ASA Standards Secretariat arranges for their publication and distribution.

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered and that a concerted effort be made towards their resolution.

The use of an American National Standard is completely voluntary. Their existence does not in any respect preclude anyone, whether he or she has approved the Standards or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the Standards.

NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken periodically to reaffirm, revise, or withdraw this Standard.



Acoustical Society of America
ASA Secretariat
35 Pinelawn Road, Suite 114E
Melville, New York 11747-3177
Telephone: 1 (631) 390-0215
Fax: 1 (631) 390-0217
E-mail: asastds@aip.org

© 2012 by Acoustical Society of America. This standard may not be reproduced in whole or in part in any form for sale, promotion, or any commercial purpose, or any purpose not falling within the provisions of the U.S. Copyright Act of 1976, without prior written permission of the publisher. For permission, address a request to the Standards Secretariat of the Acoustical Society of America.

Contents

1	Scope	1
2	Normative references.....	1
3	Terminology	1
4	Letter symbols.....	1
5	Applications.....	1
5.1	Application statement	1
5.2	Measurement types	1
5.3	Transmit and acoustic boundary considerations	1
5.4	Annexes	2
6	Procedures for measuring performance characteristics	2
6.1	Preparing transducers for measurement.....	2
6.2	Receive sensitivity methods and measurement conditions.....	4
6.3	Measurement of sensitivity and response-audio and ultrasonic frequency range	4
6.4	Directional response of sensitivity and response measurement	9
6.5	Voltage coupling loss.....	10
6.6	Electrical impedance and admittance measurements.....	10
6.7	Equivalent noise pressure	10
7	Data reporting	11
7.1	Data reporting requirements.....	11
7.2	Format of data presented	12
7.3	Specification of orientation	12
7.4	Directional response graphic representation.....	13
7.5	Presentation of electrical impedance and admittance data.....	14
8	Correction factors.....	14
8.1	Hydrophone electrical loading corrections	15
8.2	Transmit response corrections for transducers with extension cables.....	17
8.3	Attenuation correction.....	17
9	Uncertainties in free-field transducer calibrations.....	17
9.1	Introduction	17
9.2	Reported uncertainty	18
9.3	Common sources of uncertainty in free-field calibrations.....	19
9.4	Uncertainty considerations	20
10	Computation of derived characteristics	22
10.1	Directionality measures	22
10.2	Acoustic power output (P_{ac}) and acoustic power level (L_p)	24
10.3	Electrical power input (P_{el}).....	25

10.4	Transmitting efficiency (η)	25
10.5	Open-circuit effective bandwidth	26
10.6	Quality factor (Q)	26
11	References	27
	Annex A Free-field calibration in a laboratory tank	29
	Annex B Medium correction factors	32
B.1	Mass density	32
B.2	Sound speed	32
B.3	Absorption coefficient	33
	Annex C Measurement of sensitivity and response—infrasonic and low audio-frequency range	35
C.1	Coupler reciprocity calibration of a hydrophone	35
C.2	Secondary sensitivity calibration	37
	Annex D Phase of free-field voltage sensitivity via reciprocity method	39
	Annex E Nonlinear effects including cavitation	42
	Annex F Standard-target method for calibrating active sonars	46
F.1	Standard target	46
F.2	Theory	46
F.3	Applicability	48
	Bibliography	51

Figures

Figure 1	– Transducer arrangements for reciprocity calibration	5
Figure 2	– Left-handed polar coordinate system	12
Figure 3	– Example: Directional response displayed as a polar graph	13
Figure 4	– Example: Plots of resistance (R) and reactance (X) vs. frequency (top) and X vs. R (bottom)	14
Figure C.1	– Simplified schematic diagram of a liquid coupler	36
Figure D.1	– Measurement framework for supporting the three transducers in-line	40

Foreword

[This Foreword is for information only and is not a part of ANSI/ASA S1.20-2012 American National Standard Procedures for Calibration of Underwater Electroacoustic Transducers.]

This standard comprises a part of a group of definitions, standards, and specifications for use in acoustics. It was developed and approved by Accredited Standards Committee S1 Acoustics, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S1 is as follows:

Standards, specifications, methods of measurement and test, and terminology in the field of physical acoustics, including architectural acoustics, electroacoustics, sonics and ultrasonics, and underwater sound, but excluding those aspects which pertain to biological safety, tolerances, and comfort.

This standard establishes measurement procedures for calibrating underwater electroacoustic transducers and describes forms for presenting and assessing the resultant data. Both primary and secondary calibration procedures are specified for the frequency range from a few hertz to a few megahertz.

This standard is not comparable to any existing ISO Standard.

This standard includes six Informative Annexes.

At the time this Standard was submitted to Accredited Standards Committee S1, Acoustics, for approval, the membership was as follows:

P. Battenberg, *Chair*
R.J. Peppin, *Vice-Chair*

S.B. Blaeser, *Secretary*

Acoustical Society of America	A.H. Marsh P.D. Schomer (Alt.)
Air-Conditioning, Heating and Refrigeration Institute	S.J. Lind D. Abbate (Alt.)
American Industrial Hygiene Association	D. Driscoll D. Sandfort (Alt.)
Campanella Associates	A.J. Campanella
Casella USA	R. Selwyn R. Brauch (Alt.)
ETS-Lindgren Acoustic Systems	D. Winker M. Black (Alt.)
G.R.A.S. Sound & Vibration	J. Sondergaard B. Schustrich (Alt.)
Information Technology Industry Council	W.M. Beltman J. Rosenberg (Alt.)

ANSI/ASA S1.20-2012

National Council of Acoustical Consultants	E. Logsdon
.....	G.E. Winzer (Alt.)
National Institute of Standards & Technology (NIST)	V. Nedzelitsky
.....	D.J. Evans (Alt.)
PCB Group	K. Cox
.....	L. Harbaugh (Alt.)
Quest Technologies, Inc.	P.J. Battenberg
.....	M. Wurm (Alt.)
Scantek, Inc.	R.J. Peppin
.....	M. Buzduga (Alt.)
U.S. Air Force (USAF)	R. McKinley
.....	F. Mobley (Alt.)
U.S. Army Construction Engineering Research Laboratory	M. Swearingen
.....	M.J. White (Alt.)
U.S. Army Research Laboratory, Human Research and Engineering Directorate	A. Scharine
.....	T.R. Letowski (Alt.)
U.S. Department of Labor – Mine Safety and Health Administration	J.P. Seiler
.....	J. Homer (Alt.)

Individual Experts of Accredited Standards Committee S1, Acoustics

S.L. Ehrlich	P.D. Schomer
K.M. Eldred	J.P. Seiler
W.W. Lang	L. Wu
A.H. Marsh	

Working Group S1/WG 9, Calibration of Underwater Electroacoustic Transducers, which assisted Accredited Standards Committee S1, Acoustics, in the development of this standard, had the following membership.

R.M. Drake, Chair

K.G. Foote	R.M. Logan	S.P. Robinson
S.E. Forsythe	J.A. Meyers	P.D. Theobald

Suggestions for improvements of this standard will be welcomed. They should be sent to Accredited Standards Committee S1, Acoustics, in care of the Standards Secretariat of the Acoustical Society of America, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177. Telephone: 631-390-0215; FAX: 631-390-0217; E-mail: asastds@aip.org.

American National Standard

Procedures for Calibration of Underwater Electroacoustic Transducers

1 Scope

This standard establishes measurement procedures for calibrating underwater electroacoustic transducers and describes forms for presenting and assessing the resultant data. It is a revision of American National Standard S1.20-1988 (R 2003).

2 Normative references

ANSI S1.1-1994 (R 2004) *American National Standard Acoustical Terminology*

ANSI/ASA S1.8-1989 (R 2011) *American National Standard Reference Quantities for Acoustical Levels*

3 Terminology

For the purposes of this standard, the terms and definitions given in ANSI S1.1-1994 (R 2004) apply, except where otherwise specifically re-defined herein.

4 Letter symbols

Letter symbols used in this standard comply with those given in ANSI/IEEE Std 260.4-1996 *American National Standard Letter Symbols and Abbreviations for Quantities Used in Acoustics* (revision and redesignation of ANSI Y10.11-1984), ISO 80000 *Quantities and Units*, ANSI S1.1-1994 (R 2004) *American National Standard Acoustical Terminology*, and ANSI/ASA S1.8-1989 (R 2011) *American National Standard Reference Quantities for Acoustical Levels*. Additional letter symbols, when utilized, are defined within this standard.

5 Applications

5.1 Application statement

Primary and secondary calibration procedures are specified for the frequencies from a few hertz to a few megahertz.

5.2 Measurement types

Procedures are specified for determining the measurable characteristics of free-field sensitivity (more specifically identified as "free-field voltage sensitivity," a receive voltage measurement), transmitting current response, transmitting voltage response, directional response, voltage coupling loss, impedance, and equivalent noise pressure.

5.3 Transmit and acoustic boundary considerations

Transmit drive conditions and acoustic boundaries can significantly affect the quality of acoustic transmit signal measurements and therefore the quality of the computed measurement parameters. Care should always be taken to work within device-specific operating ranges and under known acoustic conditions.