2784-2-S

A BIBLIOGRAPHY ON ACOUSTIC SOURCES AND THEIR RELATED FIELDS

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February 1959

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Ann Arbor, Michigan

This study was supported by a contract, No. Nonr-1224 (24), between the Department of the Navy, Office of Naval Research Code 411, and the Willow Run Laboratories of The University of Michigan. Reproduction in whole or in part for purposes of the United States Government is hereby granted.

ABSTRACT

This report is a bibliography on acoustic sources and their related fields. Both single sources and arrays of sources have been considered. The abstracts are arranged into a detailed subject outline having four major topics: Single Sources and Receivers; Arrays of Sources and Receivers; Transducer Properties; Acoustic Fields. Articles published during the period from 1935 to 1958 are reviewed principally.

CONTENTS

1. INTRODUCTION

This bibliography is concerned with acoustic sources and their related fields. The topic of arrays is a primary consideration and references pertinent to this topic comprise a major portion of this bibliography. Since an array is a collection of single sources, a knowledge of the more elementary sources is necessary to understanding the multiple source. For this reason, simple sources are reviewed as well as various combinations of sources. Because of the direct relation between source radiation characteristics and field parameters, articles on acoustic fields are also included. In view of the relation between transducers as sources and as receivers, both are considered. Four main categories are covered:

A. Single Sources and Receivers,
B. Arrays of Sources and Receivers,
C. Transducer Properties, and,
D. Acoustic Fields.

Under Section A, simple sources of various shapes are considered. Directional characteristics of these sources are examined in many of the references. Several papers take into consideration the acoustic impedance of the source. In a few papers,examinations of the field and directivity of a source backed by a reflector are also reported.

Section B includes references on multiple sources. Subdivisions of this section include linear, circular, and other arrangements of simple sources. These papers consider the directional characteristics of a collection of simple sources, super-directivity, and radiation impedance.

In Section C references to the design and calibration of transducers are given. In these references various methods of calibration are discussed and complete descriptions of some instruments for transducer calibration are included. Also listed are abstracts of papers on the methods of relating the parameters associated with calibration.

Section D lists references on the field associated with these various sources. These papers discuss the field parameters involved and describe several field and radiation phenomena. Radiation pressure and energy relations are considered separately.

The principle sources surveyed were:

Science Abstracts, Section A (Physics), 1935-1958.
Acustica, 1952-1958.
Journal of the Acoustical Society of America, 1929-1958.
Soviet Physics-Acoustics, 1955-1958.

Other references were obtained from examination of the bibliographies of papers obtained from these sources.

2. SUBJECT OUTLINE AND METHOD OF USE

A complete subject outline listing the topics included in this bibliography follows.

A. Single Sources and Receivers

1. Point
2. Plane
3. Line
4. Cylindrical
5. Conical
6. Spherical
7. Other

B. Arrays of Sources and Receivers

1. Linear
2. Circular
3. Other

C. Transducer Properties

1. Design
2. Calibration

D. Acoustic Fields

1. General Properties
2. Radiation Pressure
3. Energy Relations

All papers have been catalogued according to this outline. To find the articles on a particular subject, refer to this outline to find the related topics. Next refer to Section 3, where the outline is repeated with the papers listed with author, date, and title for each topic. Some entries are cross-referenced. In Section 4 all the papers in the survey are listed alphabetically by author. Each listing includes the name, date, and pages of the journal where the paper can be found, as well as an abstract of the paper. A list of abbreviations of journal titles will be found in the Appendix.

3. SUBJECT OUTLINE WITH AUTHOR AND TITLE

A. Single Sources and Receivers

1. Point

Brekhovskikh, L. M. (1949) A NEW METHOD OF SOLVING THE PROBLEM OF A POINT SOURCE OF RADIATION IN A STRATIFIED-INHOMOGENEOUS MEDIUM.

Brekhovskikh, L. M. (1949) FIELD OF A POINT SOURCE OF RADIATION IN A STRATIFIED-INHOMOGENEOUS MEDIUM. I. INTEGRAL FORM OF THE SOLUTION.

Brekhovskikh, L. M. (1949) FIELD OF POINT SOURCE OF RADIATION IN A STRATIFIED-INHOMOGENEOUS MEDIUM. II. DISCUSSION OF THE SOLUTION.

Brekhovskikh, L. M. (1949) FIELD OF A POINT SOURCE OF RADIATION IN A STRATIFIED-INHOMOGENEOUS MEDIUM. III. AVERAGE LAWS OF ATTENUATION.

Fein, L. (1950) AN ULTRASONIC UNDERWATER "POINT SOURCE" PROBE.

Gazaryan, Yu. L. (1957) WAVEGUIDE PROPAGATION OF SOUND FOR ONE CLASS OF INHOMOGENEOUS LAMELLAR MEDIA.

Pritchard, R. L. (1951) DIRECTIVITY OF ACOUSTIC LINEAR POINT ARRAYS.

Pritchard, R. L. (1953) OPTIMUM DIRECTIVITY PATTERNS FOR LINEAR POINT ARRAYS.

Pritchard, R. L. (1953) APPROXIMATE CALCULATION OF THE DIRECTIVITY FACTOR OF LINEAR POINT ARRAYS.

Pritchard, R. L. (1954) MAXIMUM DIRECTIVITY INDEX OF A LINEAR POINT ARRAY.

Walters, A. G. (1951) ON THE PROPAGATION OF DISTURBANCES FROM MOVING SOURCES.

Welkowitz, W. (1956) DIRECTIONAL CIRCULAR ARRAYS OF POINT SOURCES.

2. Plane

Carter, A. H., and Williams, A. O., Jr. (1951) A NEW EXPANSION FOR THE VELOCITY POTENTIAL OF A PISTON SOURCE.

Chetaev, D. N. (1953) ACOUSTIC RESISTANCE OF A MOVING PLANE EMITTER.

Feik, K. (1955) DIRECTIONAL SOUND.

Fischer, F. A. (1951) THE RADIATION OF IMPULSES FROM PLANE PISTON MEMBRANES IN A RIGID WALL.

Fischer F. A. (1952) ON THE RELATION BETWEEN DIRECTIVITY FACTOR AND AMPLITUDE DISTRIBUTION IN LINEAR AND PLANE RADIATION SYSTEMS.

Fox, F. E., and Rock, G. D. (1938) ULTRASONIC RADIATION FIELD OF A QUARTZ DISC RADIATING INTO A LIQUID MEDIA.

Guptill, E. W. (1953) THE SOUND FIELD OF A PISTON SOURCE.

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Ingard, U., and Pridmore-Brown, D. (1956) SOUND RADIATION FROM THE ACOUSTIC BOUNDARY LAYER.

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Meixner, J., and Fritze, U. (1949) THE SOUND FIELD IN THE VICINITY OF A FREE VIBRATING PISTON DIAPHRAGM.

Pachner, J. (1949) PRESSURE DISTRIBUTION IN THE ACOUSTICAL FIELD EXCITED BY A VIBRATING PLATE.

Ponomarev, P. V. (1957) TRANSIENT PROCESSES IN PIEZO-VIBRATORS.

Slaymaker, F. H., Meeker, W. F., and Merrill, L. L. (1946) THE DIRECTIONAL CHARACTERISTICS OF A FREE-EDGE DISK MOUNTED IN A FLAT BAFFLE OR IN A PARABOLIC HORN.

Toulis, W. J. (1957) RADIATION LOAD ON ARRAYS OF SMALL PISTONS.

White, J. E. (1950) A METHOD FOR MEASURING SOURCE IMPEDANCE AND TUBE ATTENUATION.

Williams, A. O. (1951) THE PISTON SOURCE AT HIGH FREQUENCIES.

3. Line

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Lapwood, E. R. (1949) THE DISTURBANCE DUE TO A LINE SOURCE IN A SEMI-INFINITE ELASTIC MEDIUM.

McKinney, C. M., and Anderson, C. D. (1954) EXPERIMENTAL INVESTIGATION OF WEDGE HORNS USED WITH LINE HYDROPHONES.

McKinney, C. M., and Owens, W. R. (1955) WEDGE-SHAPED ACOUSTIC HORNS FOR UNDERWATER SOUND APPLICATIONS.

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Thiessen, G. J. (1955) ON THE EFFICIENCY OF AN ACOUSTIC LINE SOURCE WITH PROGRESSIVE PHASE SHIFT.

Tucker, D. G. (1957) ARRAYS WITH CONSTANT BEAM-WIDTH OVER A WIDE FREQUENCY-RANGE.

4. Cylindrical

Bacchi, G. (1948) DIRECTIONAL CHARACTERISTICS OF A CYLINDRICAL ACOUSTIC RADIATOR WITH A CONICAL REFLECTOR.

Federici, M. (1957) DIRECTIONAL CHARACTERISTICS AND (ACOUSTIC) IMPEDANCE OF AN ARTIFICALLY COMPENSATED VIBRATING CYLINDRICAL SOURCE.

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Lax, M., and Feshbach, H. (1947) ON THE RADIATION PROBLEM AT HIGH FREQUENCIES.

5. Conical

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Takeushi, R. (1950) THE DIRECTIONAL CHARACTERISTICS OF CONICAL REFLECTORS.

Wolff, I., and Malter, L. (1958) DIRECTIONAL RADIATION OF SOUND.

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Pritchard, R. L. (1953) THE DIRECTIVITY OF SPHERICAL MICROPHONES.

Rzhevkin, S. N. (1949) ENERGY MOVEMENT IN THE FIELD OF A SPHERICAL SOUND RADIATOR.

7. Other

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Keck, W., Heller, G. S., and Williams, A. O., Jr. (1951) MEASUREMENTS OF THE UNDERWATER SOUND FIELD GENERATED BY QUARTZ TRANSDUCERS.

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Foster, R. M. (1926) DIRECTIVE DIAGRAMS OF ANTENNA ARRAYS.

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Feik, K. (1955) DIRECTIONAL SOUND.

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Feik, K., and Brodhun, D. (1955) ON THE DIRECTION FACTOR AND ACOUSTIC POWER-CONCENTRATION OF A CIRCULAR (LINE) GROUP OF RADIATORS.

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Bauer, B. B. (1953) TRANSFORMER COUPLINGS FOR EQUIVALENT NETWORK SYNTHESIS.

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Florisson, C. (1956) PROCEDURE FOR THE CALIBRATION OF AN ACOUSTIC PROBE BY MEANS OF AN ABSOLUTE PENDULUM FOR RADIATION PRESSURE.

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Mayer, N. (1953) THE EVALUATION OF THE DIRECTIONAL CHARACTERISTICS OF SOUND TRANSMITTERS AND RECEIVERS.

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Zverev, V. A. (1956) THE POSSIBILITY OF AN ABSOLUTE CALIBRATION OF RADIATORS AND RECEIVERS OF SOUND WITH RESPECT TO RADIATION PRESSURE WITHOUT USING A RADIOMETER.

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4. ABSTRACTS

Anan'eva, A. A. (1956) NON-DIRECTIVE CERAMIC SOUND RECEIVERS. Sov. Phys.-Acoust., 2, 8-24.

An examination is made of piezo-electric sound receivers, possessing spherical and cylindrical directivity and consisting of a thin envelope of barium titanate ceramic. With suitable choice of the material and appropriate arrangement of electrodes it is possible to obtain great sensitivity with good directivity characteristics.

Anderson, C. D.; see McKinney, C. M., and Anderson, C. D. (1954)

Anderson, C. D.; see Mechler, M. V., McKinney, C. M., Anderson, C. D., and Collins, F. A. (1957)

Awatani, J. (1955) STUDIES ON ACOUSTIC RADIATION PRESSURE. I. GENERAL CONSIDERATIONS. J. Acoust. Soc. Am., 27, 278-281.

The equation derived by Kotani and King relating to the excess pressure valid to the second order in the acoustic field is examined. It is shown that the solution of the usual wave equation can be used in the case when the radiation pressure in the Langevin's sense is derived from this equation. The reason why not only the normal force but also the tangential force on the non-stiff surface result from the radiation pressure defined from the viewpoint of the pressure in the hydrodynamics, is clarified by considering the motion of the surface. The general expression for the radiation pressure on a rigid object in motion due to the inertia effect is developed by introducing moving co-ordinates.

Bacchi, G. (1948) DIRECTIONAL CHARACTERISTIC OF A CYLINDRICAL ACOUSTIC RADIATOR WITH A CONICAL REFLECTOR. Alta Frequenza, 17, 74-78.

A form of cylindrical magnetostriction radiator with a conical reflector arranged on its axis has a directional characteristic with an absolute maximum on the axis. The wavelengths used are of the same order as the dimensions of the radiator. If the reflector has a 45° opening, the characteristic is represented by the integral of the zero-order Bessel function.

Bachynski, M. P., and Bekefi, G. (1957) STUDY OF OPTICAL DIFFRACTION IMAGES AT MICROWAVE FREQUENCIES. J. Acoust. Soc. Am., 47, 428-438.

Experimental investigations of the intensity distribution in the region of the focus of microwave lenses are described. The circularly symmetric lenses, made from polystyrene plastic, were illuminated by a linearly polarized beam of radiation of 1.25 cm wavelength. Most of the measurements are presented in the form of intensity contours in planes both containing the principal ray and lying perpendicular to it. Images formed by nearly perfect optical systems and by systems suffering from various third-order monochromatic aberrations were examined. In most cases the results are compared with calculations made from the scalar-diffraction theory of optical systems. In general, good agreement between theory and experiment is found.

Some preliminary measurements of the phase variations of the electromagnetic field in the vicinity of the focus are given and the results discussed.

Barkhatov, A. N. (1958) ACOUSTIC FIELD IN A MEDIUM WITH A HOMOGENEOUS SURFACE LAYER. Sov. Phys.-Acoust., 4, 11-16.

The acoustic field is investigated for a space bounded by a surface layer over an extended medium, in which there is a constant negative gradient of the velocity of sound, for various positions of the radiator. The results for geometrical and wave theories are compared.

Bauer, B. B. (1953) TRANSFORMER COUPLINGS FOR EQUIVALENT NETWORK SYNTHESIS. J. Acoust. Soc. Am., 25, 837-840.

It may be shown that regardless of the type of analogy chosen ("impedance" v. "mobility"), disconformity will be encountered in synthesizing the equivalent network of a mechano-acoustic array. A method is described employing transformer couplings for getting around this difficulty. As a result, it becomes possible to construct equivalent circuits of mechanical arrays in a simple and straightforward manner by the method of impedance analogy. Similar benefits are achieved for the method of mobility analogy in the synthesis of equivalent circuits of acoustic arrays. Equivalent networks for certain mechano-acoustic arrays which cannot be conventionally synthesized become feasible through this method.

Bekefi, G.; see Bachynski, M. P., and Bekefi, G. (1957)

Berman, A., and Clay, C. S. (1957) THEORY OF TIME-AVERAGED-PRODUCT ARRAYS. J. Acoust. Soc. Am., 29, 805-812.

The mathematical analysis of the directional characteristics of linear additive arrays is given in a polynomial representation. The result of multiplying and taking a time average of the outputs of several detectors also has directional characteristics that may be expressed as polynomials. It is shown that the same directional characteristics may be obtained from multiplicative arrays having a small number of detectors as with an additive array with a large number of elements. The length of the multiplicative array is about half the length of the additive array having the same directional characteristics.

Bergtold, F. (1951) THE ARRANGEMENT OF SOUND SOURCES IN ROOMS AND AUDITORIA. Fernmeldetech, Z., 4, 112-116. (In German)

The paper is concerned mainly with the design of loud-speaker systems for large auditoria. Banks of loud-speakers are arranged (a) flush with the walls, (b) recessed in the wall but set alternately looking left and right at an angle to the wall, and (c) two banks of speakers in walls (or baffles) inclined to each other at a suitable angle. Sections of the paper deal with the problems of equalizing the sound intensity over the listening area, equal frequency range for all listeners, background noise, reverberation effects, directionality and strength of sound sources. Detailed consideration is given to the use of sound radiator groups in a church, making allowance for directionality in the horizontal and vertical planes. An attempt is made to spread the sound fanwise as widely as possible over the audience whilst limiting the spread in a vertical direction to avoid reflections. The sound intensity is also controlled to a minimum value to limit disturbing reflections.

Beyer, R. T. (1950) RADIATION PRESSURE IN A SOUND WAVE. Am. J. Phys., 18, 25-29.

Considerable confusion has arisen as to the precise meaning of the term radiation pressure, and as to what is actually measured by experiment. During recent years, a number of papers have appeared in German journals, clarifying the problem, while a lengthy mathematical formulation has been given by Brillouin. However, to the writer's knowledge, no similar work has appeared in English. The purpose of this paper is to fill the gap, at least in part. The simple picture of radiation pressure which is given is largely that of Hertz and Mende.

Blochintzev, D. I. (1942) EMISSION OF SOUND BY A MOVING SOURCE. J. Phys., USSR, 6, 230.

Bordone, C. (1954) SOME ASPECTS OF THE NONLINEAR DISTORTION OF LOUDSPEAKERS. Acustica, 4, 563-566.

Measurements have shown that this depends greatly upon the frequency and direction of radiation. When describing the nonlinear behavior of loudspeakers considerable attention should be paid to this fact.

Bordoni, P. G. (1945) THE CONICAL SOUND SOURCE. J. Acoust. Soc. Am., 17, 123-126.

An asymptotic expansion has been derived which allows the plotting of directional and response curves for a vibrating cone in an infinite baffle. The results are compared with those pertaining to a flat disc of the same radius.

Bouwkamp, C. J. (1946) A CONTRIBUTION TO THE THEORY OF ACOUSTIC RADIATION. Philips Res. Rep., 1, 251-277.

The field of radiation in an ideal medium produced by a harmonically oscillating membrane with arbitrary amplitude distribution in a closely fitting aperture of an infinite rigid plane is studied mathematically. The problem is stated by means of the velocity potential in the form of a boundary value problem in connection with the wave equation. A new argument is given as to why the time factor exp $(-i\omega t)$ is preferred. The general formulae are applied to a circular membrane, and King's theory is very much extended.

Brekhovskikh, L. M. (1949) A NEW METHOD OF SOLVING THE PROBLEM OF A POINT SOURCE OF RADIATION IN A STRATIFIED-INHOMOGENEOUS MEDIUM. Izv. Akad. Nauk, SSSR, Ser. Fiz., 13, 409-420. (In Russian)

The theory is developed in parallel for the acoustical and electromagnetic case and does not use the wave equation which in this case leads to insurmountable difficulties, but from Hertz's vector of an elementary dipole. The basic difficulty of the investigation consists in the fact that the medium and the wave possess different symmetries. This can be overcome, however, by resolving the spherical wave into plane waves and analyzing the behavior of the individual plane waves. A close analogy between the problem considered and diffraction phenomena is then observed, and the method followed in the latter case also proves its value here. There is no objection to resolving the original wave into wavelets having the same symmetry character as the object on which they are diffracted, or, in the case considered here, as the stratified medium. The method yields the discrete spectrum, lateral waves and other characteristics of this particular case.

Brekhovskikh, L. M. (1949) FIELD OF A POINT SOURCE OF RADIATION IN A STRATIFIED-INHOMOGENEOUS MEDIUM. I. INTEGRAL FORM OF THE SOLUTION. Izv. Akad. Nauk, SSSR, Ser. Fiz., 13, 505-514. (In Russian)

A generalization of former work of the author [Dokl. Akad. Nauk, SSSR, 48 (1945); Izv. Akad. Nauk, SSSR, Ser. Fiz., 10 (1946)] and P. A. Ryazin by including propagation of waves in a stratum bounded not only by sharp but also by "washed-out" surfaces of separation. As in the earlier work, the problem is treated for the electromagnetic in parallel with the acoustic case. The integral solution involving Bessel functions is transformed into another involving Hankel functions, i.e., the expression of the plane wave, and is supplemented by another representing the spherical waves. The author then uses Weyl's well-known method introducing the Hertz vector for obtaining phase relations and Fresnel reflection coefficients. The usefulness of the solution is shown by 4 cases and a supplement adds the existence and uniqueness theorems.

Brekhovskikh, L. M. (1949) FIELD OF A POINT SOURCE OF RADIATION IN A STRATIFIED-INHOMOGENEOUS MEDIUM. II. DISCUSSION OF THE SOLUTION. Izv. Akad. Nauk, SSSR, Ser. Fiz., 13, 515-533. (In Russian)

The author shows that the solution obtained in the first part is of practical use, i.e., not only suitable for idealized problems. The integral representing spherical waves is resolved into plane waves and so-called inhomogeneous waves, the latter formally equivalent to plane waves, but with complex angles of incidence. The integral solution is evaluated by complex integration, the expressions obtained representing the "discrete" and "continuous" wave spectrum of the problem. A comprehensive analysis of the lateral waves by a method of the author published earlier (Izv. Akad. Nauk, SSSR, Ser. Fiz., 10, 491); and of the discrete spectrum is followed by two practical examples, the second of which represented the case of a plane waveguide with walls of finite thickness.

Brekhovskikh, L. M. (1949) FIELD OF A POINT SOURCE OF RADIATION IN A STRATIFIED-INHOMOGENEOUS MEDIUM. III. AVERAGE LAWS OF ATTENUATION. Izv. Akad. Nauk, SSSR, Ser. Fiz., 13, 534-545. (In Russian)

The two kinds of waves emitted by the source, viz. those of the "discrete" spectrum and the two lateral waves, are damped according to two different laws; the first of the form exp $[(-\beta_e r)/\sqrt{r}]$, and the second of the form exp $[(-\gamma_i r)/r^2]$ where the two coefficients β_e, γ_i are imaginary. The physical character of the damping process is also different in the two cases, viz. a leakage of energy through the boundary layers in the first case, in the second, absorption of the waves in the boundary layers. At a great distance from the source the field is determined by the least damped wave of the discrete spectrum, or by the lateral waves; at short distances, however, other waves of the discrete spectrum become important too, whereas the lateral waves have only a negligible influence. The field in the layer has a complicated interference structure owing to the superposition of the waves of the discrete spectrum. The formulae of Parts I and II permit of averaging processes which simplify the picture and make physical sense.

Brillouin, L. (1956) RADIATION PRESSURES AND THEIR TENSORIAL ASPECT. J. phys. radium, 17, 379-383. (In French)

Emission, absorption and reflection of elastic waves result in forces known as radiation pressure. For an unperturbed plane wave it is possible to compute the average tensor of stresses, from which the force on any obstacle can be obtained. This fundamental tensor is discussed first for a nondispersive medium and second for a dispersive medium. Some examples and applications are given. The problem of scattering by a sphere is of special interest, and its discussion leads to a correct definition of the scattering cross section.

Brodhun, D.; see Feik, K., and Brodhun, D. (1955)

Brodin, J. (1949) GENERAL EXPRESSION OF HUYGHENS PRINCIPLE FOR DAMPED PROPAGATION OF LONGITUDINAL WAVES. Compt. rend. (Paris), 229, 989-991. (In French)

A wave, emitted by sources inside a domain limited by a surface S is, outside S, identical with a wave emitted by sources distributed over the surface S. Assuming a medium which is not perfectly transparent, the author derives all the solutions of Huyghens principle as stated above.

Brown, W. N., Jr. (1941) THEORY OF CONICAL SOUND RADIATORS. J. Acoust. Soc. Am., 13, 20-22.

An expression is derived for the sound pressure resulting from the vibration of a conical sound radiator and the sound field is compared with that generated by a plane piston.

Byard, S. (1948) NOTE ON THE IMPEDANCE VARIATIONS OF AN ELECTRO-ACOUSTIC TRANSDUCER IN A REFLECTING FIELD. Proc. Phys. Soc. (London), 61, 478-480.

When a reflecting surface is introduced into the field of an electroacoustic transducer so that a certain proportion of the radiated energy is returned to the source, the measured electrical impedance of the transducer will vary according to the relative phasing of the returned energy. Consequently if the reflecting surface be moved towards or away from the transducer, or alternatively, if the frequency of the electrical input be varied, periodic fluctuations may be observed in the input voltage or current. The Pierce interferometer uses this effect in determining acoustic wavelength in a liquid or gas. The purpose of this note is to relate the impedance changes responsible for the voltage and current fluctuations to the efficiency of the electroacoustic device by making use of the reciprocity principle. It is also indicated how, in theory at least, the absolute calibration of a projector or a receiver may be obtained by impedance measurements on a single instrument, and how this is related to Carstensen's more practical "self-reciprocity" method of determining transducer constants.

Cady, W. G. (1950) PIEZOELECTRIC EQUATIONS OF STATE AND THEIR APPLICATION TO THICKNESS-VIBRATION TRANSDUCERS. J. Acoust. Soc. Am., 22, 579-583.

The electromechanical equations of state are written in a number of forms, extending from Voigt's formulation to the recently introduced formulation with g and h as the piezoelectric constants. Those equations that are most appropriate in the theoretical treatment of the two chief types of crystal transducer are pointed out. A detailed treatment of the thickness-vibration transducer is then given, leading to expressions for the electrical characteristics and for the acoustic vibrational amplitude and intensity. Some special cases are also considered.

Cady, W. G. (1953) GRAPHICAL AIDS IN INTERPRETING THE PERFORMANCE OF CRYSTAL TRANSDUCERS. J. Acoust. Soc. Am., 25, 687-696.

When the mechanical damping of a transducer is large, as by acoustic radiation from one or both faces into a liquid or solid, the circular diagram that represents its characteristics requires special treatment. As a background for this treatment, the uses and limitations of the conventional circle for a resonator with small losses are first reviewed. The problem of the transducer with large losses is then considered with special reference to the equations and graphs for a thickness-type transducer with unsymmetrical loading. For plane-wave transducers the expressions are exact for all loads and at all frequencies, including harmonics. Either the voltage or the current may be constant. From the admittance or impedance diagrams the magnitude and phase of current, voltage, particle velocity and vibrational amplitude at any frequency can be obtained immediately. Similar results would be found with plates in lengthwise vibration. A new type of diagram is developed for representing vibrational amplitudes. As an illustration the case of a quartz plate radiating into three liquids of widely different acoustic properties is treated. When the load is unsymmetrical, there is no true node anywhere in the crystal except when the load is zero or infinity. There is, however, a plane of minimal vibration, the amplitude and location of which are derived. The equations indicate certain peculiar effects when the specific acoustic resistance of the medium is just twice that of the crystal.

Calaora, A., and Gavreau, V. (1956) ABSOLUTE CALIBRATION OF MICROPHONES AT AUDIBLE AND INFRASONIC FREQUENCIES. Compt. rend. (Paris), 243, 1840-1842. (In French)

The particle amplitude in a sound field (0-400 c/s) at a probe tube microphone, in either an anechoic room or an acoustically lagged pipe, was determined from the alternating phase--changes in an ultrasonic field of known wavelength superposed on the sound field.

Camp, L. (1948) THE MAGNETOSTRICTIVE RADIAL VIBRATOR. J. Acoust. Soc. Am., 20, 289-293.

A description is given of a radial vibrator used in underwater sound signaling. A technique is presented for providing a plastic cast to protect the windings which serves to improve rather than decrease the potential efficiency. Data are presented to show the operating characteristics of these sound sources.

Camp, L., and Wertz, F. D. (1949) A LOW "Q" DIRECTIONAL MAGNETOSTRICTIVE ELECTRO-ACOUSTIC TRANSDUCER. J. Acoust. Soc. Am., 21, 382-384.

The description of a lamination design for the magnetostrictive motors of a directional transducer array. The design makes possible the efficient operation of the transducer with a "Q" of 6 under a full water load. Array patterns are presented to show that the laminated motors radiate as plane pistons into the medium.

Carlisle, R. W. (1943) CONDITIONS FOR WIDE-ANGLE RADIATION FROM CONICAL SOUND RADIATORS. J. Acoust. Soc. Am., 15, 44-49.

The loud-speaker cone is approximated to an array of pairs of point sources and conditions of wide-angle radiation depend on the selection of the cone angle, the number and depth of the corrugations, and the weight and stiffness of the cone material.

Carter, A. H., and Williams, A. O., Jr. (1951) A NEW EXPANSION FOR THE VELOCITY POTENTIAL OF A PISTON SOURCE. J. Acoust. Soc. Am., 23, 179-184.

The Rayleigh surface integral, giving the velocity potential for a plane piston source surrounded by an infinite rigid flange, reduces to a line integral when the coordinates are suitably chosen. As shown by Schoch, for points within the goemetrical cylinder whose base is formed by the piston surface, the line integral is expressible as a plane wave term plus a "perturbation" integral. For external points, a different integral results. In the present work, these two complementary expressions are evaluated for a circular piston, as series of half-integral order Hankel functions in kz and polynomials in x/a; k = the propagation constant, a = the piston radius, z = the axial and x = the radial coordinate of a field point. The resulting rigorous equation (valid for points not on the piston surface) converges for any value of ka, provided $z > a$. For large values of kz, where asymptotic formulas apply, the expression assumes a particularly simple form. Sample calculations have been made for $ka = 10$, $z = 10a$ and $ka = 50$, $z = 50a$. Also an approximate expansion has been derived which may be more useful than the rigorous result in paraxial regions.

Chetaev, D. N. (1951) ON SOUND EMISSION BY MEANS OF A PISTON. Dokl. Akad. Nauk, SSSR, 76, 813-816. (In Russian)

The integral $\phi = v/2\pi \iint (e^{-ikr}/r)dS$ arising as solution of $\Delta\phi + k^2\phi = 0$ is investigated subject to certain boundary conditions. An asymptotic solution for large k and a formula for a rectangular piston are deduced.

Chetaev, D. N. (1953) ACOUSTIC RESISTANCE OF A MOVING PLANE EMITTER. Dokl. Akad. Nauk, SSSR, 90, 355-358. (In Russian; English translation, U. S. National Sci. Found., NSF-tr-89.)

A mathematical paper dealing with the emission of sound from a plane plate, in an opening in a semi-infinite rigid wall, radiating into an ideal compressible fluid moving with a constant velocity which is smaller than the velocity of sound. A general expression is derived for the acoustic resistance R and reactance X of the vibrating plate, and applied to the special case of a square plate. A table of values of R and X is given for values of ka ranging from 1 to 10.

Clark, M. A. (1953) AN ACOUSTIC LENS AS A DIRECTIONAL MICROPHONE. J. Acoust. Soc. Am., 25, 1152-1153.

An acoustic lens combined with a conical horn can be used to obtain a highly directional microphone without some of the disadvantages of the parabolic microphone. The directional characteristics can be calculated satisfactorily if one assumes that the horn provides uniform flooding of the lens aperture.

Clay, C. S.; see Berman, A., and Clay, C. S. (1957)

Cohen, H.; see Laird, D. T., and Cohen, H. (1952)

Collins, F. A.; see Mechler, M. V., McKinney, C. M., Anderson, C. D., and Collins, F. A. (1957)

Davids, N., Thurston, E. G., and Mueser, R. E. (1952) THE DESIGN OF OPTIMUM DIRECTIONAL ACOUSTIC ARRAYS. J. Acoust. Soc. Am., 24, 50-56.

A transducer array has been designed according to underlying theory originally applied to broadside electromagnetic aerial arrays by Dolph. The properties of Chebyshev polynomials have been employed to obtain an optimized relationship between minor-lobe level and main beam width. The shading design of a 130-element circular array is carried out utilizing a distance between stack centres of $5\lambda/8$. Experimental measurements of the resulting transducer give a peak sensitivity of -70 db below 1 for a field of 1 dyne per cm^2, 11° main beam width at the 3-db down points and suppression of side lobes to more than 32 db below peak sensitivity.

Degrois, M. (1955) STUDY OF A DETECTOR OF ULTRASONIC ENERGY. Ann. Telecomm., 10, 2-7. (In French)

Following a brief review of existing methods of obtaining the directivity of ultrasonic projectors, an apparatus involving a thermocouple detector is described. Its construction, method of use and calibration are given in detail. The apparatus is simple and enables measurements to be made in liquids without errors due to temperature variations in the liquid bath.

Diestel, H. G.; see Meyer, E., and Diestel, H. G. (1952)

Embleton, T.F.W., and Thiessen, G. J. (1958) EFFICIENCY OF A LINEAR ARRAY OF POINT SOURCES WITH PERIODIC PHASE VARIATION. J. Acoust. Soc. Am., 30, 1124-1127.

The radiation efficiency of a uniform linear array of point sources with periodic phase variation is evaluated. Two different types of interference are found depending on whether the characteristic length of the phase variation is greater or less than the wavelength of the sound radiated. In its application to suction roll silencing in paper mills it is found to be less effective than a linear continuous phase variation.

Enns, J. H., and Firestone, F. A. (1942) SOUND POWER DENSITY FIELDS. J. Acoust. Soc. Am., 14, 24-31.

A graphical presentation of the streaming of acoustical energy near vibrating radiators and reflecting surfaces is developed. The sound power density field from a simple source, a doublet source, a single point source before a totally reflecting plane (free as well as rigid), and a piston vibrating in an infinite fixed wall, is considered analytically. Formulae are worked out for computation of per cent of total radiation flowing through a certain area. By interpolation of the graphs from these equations, the flow of energy for the several radiation fields is shown.

Ewaskio, C. A., and Mawardi, O. K. (1950) ELECTROACOUSTIC PHASE SHIFT IN LOUDSPEAKERS. J. Acoust. Soc. Am., 22, 444-448.

Direct measurements of envelope delay have been obtained for a series of commercial and experimental loudspeakers. The modulation phase shift method of Nyquist and Brand has been adapted for direct indication of envelope delay by utilizing an electronic phase meter. A continuous record of the delay is obtained by an automatic level recorder suitably connected to the phase-meter. Pressure-amplitude curves measured under the same conditions provide data for a preliminary attempt to interpret the correlation between delay response and pressure response.

Fabelinski, I. L.; see Motulevich, G. P., and Fabelinski, I. L. (1957)

Farnell, G. W. (1958) MEASURED PHASE DISTRIBUTION IN THE IMAGE SPACE OF A MICRO-WAVE LENS. Can. J. Phys., 36, 935-943.

Detailed measurements at a wavelength of 3.2 cm have been made of the phase distribution in the diffraction image produced by an aberration-free lens illuminated from a point source. The behavior of the phase of the electric field is shown by contours of constant phase (wavefronts) in the plane of the image space containing the axis and the H-vector of the radiating source. The region of the image space considered extends from the solid dielectric lens to a surface somewhat beyond the focus. Results are also shown of the phase distribution measured within about one wavelength of certain phase singularities which occur at the minima of intensity on the focal arc and on the axis. In general, there is very good agreement between plots of measured phase contours and plots of phase contours previously calculated from scalar diffraction theory.

Federici, M. (1957) DIRECTIONAL CHARACTERISTICS AND (ACOUSTIC) IMPEDANCE OF AN ARTIFICIALLY-COMPENSATED VIBRATING CYLINDRICAL SOURCE. Ricerca Sci., 27, 1826-1838.

A sound source, formed by a vibrating cylinder with a radial velocity varying in phase, is examined and it is shown with this source it is possible to concentrate sound in the direction of the axis of the cylinder. The directional characteristic and gain are obtained. An indication is given of how such a source can be realized practically by means of barium titanate cylinders. The radiation impedance of the cylinder is calculated, and it is shown that for an infinite cylinder the impedance is given by the ratio of two Hankel functions of the first order.

Feher, K. (1956) THE DETERMINATION OF THE AMPLITUDE DISTRIBUTION OVER PLANE SURFACES FROM THE DIRECTIONAL PATTERN OF THEIR RADIATION FIELDS. Arch. elekt. Übertragung, 10, 125-131. (In German)

The magnitude and phase of the amplitude distribution of an oscillating surface is linked with its far-field directional radiation pattern by a Fourier integral. If one of these two quantities is known, the other can be determined from it. This paper contains firstly the theoretical foundations of a determination of the amplitude distribution by a Fourier analysis of its directional radiation pattern, secondly a description of an experimental method, and thirdly a means of checking the method of measurement with the aid of oscillating plane plates and electrostatically excited diaphragms. The method has applications in ultrasonics where a direct measurement of the amplitude distribution with a detector for solid-borne sound meets with great difficulties.

Feik, K. (1955) DIRECTIONAL SOUND. Hochfrequenztech. u. ElektAkust., 64, 35-62. (In German)

The theory is given of the directional propagation of sound from various types of sound source. Consideration is given to the radiated sound power, the directional characteristics and amplification factor of various arrays and combinations of sound sources. These include: (1) piston sources; (2) line groups; (3) circular groups; (4) spherical groups; (5) single and double radiators, and combination of these. Diagrams are given of the radiation characteristics of these groups, and three-dimensional models are also reproduced.

Feik, K. (1957) ON THE DIRECTIONAL CHARACTERISTICS OF A CIRCULAR-ARC ARRAY OF ACOUSTIC RADIATORS. Hockfrequenztech. u. ElektAkust., 66, 29-37. (In German)

The quality of a loudspeaker is determined by its linear and nonlinear distortion. The avoidance of linear distortion requires that the directional characteristic of the loudspeaker should be independent of frequency. The author describes a theoretical and experimental investigation of the directional characteristics of circular-arc arrays of sound transmitters as a function of frequency. The cases considered include uncompensated and compensated groups of transmitters, and groups of directional single transmitters arranged on the arc of a circle. Special consideration is given also to the directional characteristics of a semi-circular arrangement of sound radiators. The frequencies used in the experiments cover the range 0.9 to 11.4 kc/s. The directional curves indicate, in certain arrangements, an almost non-directional characteristic (except perhaps in the backward direction) over the whole frequency-range examined.

Feik, K., and Brodhun, D. (1955) ON THE DIRECTION FACTOR AND ACOUSTIC POWER-CONCENTRATION OF A CIRCULAR (LINE) GROUP OF RADIATORS. Nachrichtentechnik, 5, 149-150. (In German)

After referring to the work of Stenzel on the calculation of direction factors and of Fischer on the calculation of radiation efficiency, for various arrays of sound radiators, the author derives expressions for the radiation characteristics and power concentration of a circular (line) array of sound radiators.

Fein, L. (1950) AN ULTRASONIC UNDERWATER "POINT SOURCE" PROBE. J. Acoust. Soc. Am., 22, 876-877.

A conically shaped piezo-electric probe of ammonium dihydrogen phosphate is described. Its sensitivity over a frequency range from 1235 to 1280 kc/s was obtained by means of a reciprocity calibration. The average value is about 0.12 V/dyne/cm^2. Since the measured pattern of the probe as a receiver was the same at various points in the acoustic field, it may be concluded that the probe is a "point source."

Feshbach, H.; see Lax, M., and Feshbach, H. (1947)

Firestone, F. A.; see Enns, J. H., and Firestone, F. A. (1942)

Fischer, F. A. (1952) ON THE RELATION BETWEEN DIRECTIVITY FACTOR AND AMPLITUDE DISTRIBUTION IN LINEAR AND PLANE RADIATION SYSTEMS. Akust. Beih., 1, 11. (In German)

The general relations are discussed for continuous and discontinuous radiators.

Fischer, F. A. (1951) THE RADIATION OF IMPULSES FROM PLANE PISTON MEMBRANES IN A RIGID WALL. Acustica, 1, 35-39. (In German)

When impulses are radiated from a rigid disk a distortion occurs which is a function of the direction of radiation, for the individual components in the spectrum of the impulse have different direction characteristics, depending on the frequency. Calculation shows that a radiated unit impulse can be considered as composed of partial impulses from surface-elements of the disk and is conditioned by the shape of the latter. With a given impulse form, a resultant effect of the shapes of the impulse and of the disk is obtained.

Florisson, C. (1956) PROCEDURE FOR THE CALIBRATION OF AN ACOUSTIC PROBE BY MEANS OF AN ABSOLUTE PENDULUM FOR RADIATION PRESSURE. J. phys. radium, 17, 411-412. (In French)

Foldy, Leslie L., and Primakoff, Henry (1945) A GENERAL THEORY OF PASSIVE LINEAR ELECTROACOUSTIC TRANSDUCERS AND THE ELECTROACOUSTIC RECIPROCITY THEOREM, I. J. Acoust. Soc. Am., 17, 109-120.

A theory of the operation of passive linear electroacoustic transducers is developed on the basis of the most general linear equations (in this case, integral equations) relating the pressure and normal velocity at each point on the transducer surface and the voltage and current at the transducer's electrical terminals. These, together with the appropriate solutions of the wave equation expressed through the use of Green's functions for the medium in which the transducer is immersed and the equations defining the electrical termination of the transducer, completely characterize the behavior of the transducer and allow explicit calculation of such quantities as impedances, responses, etc., in terms of four parameters entering the fundamental equations.

On the basis of this theory, a proof of the reciprocity theorem for electroacoustic transducers relating their speaker and microphone responses is presented embodying the conditions necessary for its validity. These conditions are essentially the existence of certain symmetry relationships among the transducer parameters. When these symmetry relationships may be expected to hold is to be discussed in Part II of this paper which will appear later. Some applications of the theory are presented and others are outlined.

Foldy, Leslie L. (1949) THEORY OF PASSIVE LINEAR ELECTROACOUSTIC TRANSDUCERS WITH FIXED VELOCITY DISTRIBUTION. J. Acoust. Soc. Am., 21, 595-604.

A general theory is developed and applied to the calculation of important practical parameters of the transducer. A proof of the electroacoustic reciprocity theorem for such transducers is included. Another important theorem, the available acoustic power theorem, which states that the maximum power which can be absorbed by such a transducer from a plane wave sound field is given by the product of the intensity of the wave and the quantity $\lambda^2\delta_R/4\pi$ where λ is the wavelength of the wave and δ_R is the receiving directivity factor of the transducer relative to the direction of incidence of the wave is also proved. The paper concludes with a discussion of the available power efficiency of a transducer and its relation to the threshold pressure of the transducer.

Foster, Ronald M. (1926) DIRECTIVE DIAGRAMS OF ANTENNA ARRAYS. Bell System Tech. J., 5, 292-307.

Two systematic collections of directive amplitude diagrams are shown for arrays of 2 and of 16 identical antennae spaced at equal distances along a straight line with equal phase differences introduced between the currents in adjacent antennae, assuming that each antenna radiates equally in all directions in the plane of the diagram. Three diagrams show the effect of distributing the antennae over an area.

Fox, F. E., and Rock, G. D. (1938) ULTRASONIC RADIATION FIELD OF A QUARTZ DISC RADIATING INTO LIQUID MEDIA. Phys. Rev., 54, 223-228.

The radiation pressure of sound waves on a spherical obstacle is used to determine the distribution of intensity in the sound field of a quartz disc radiating into a liquid medium. The measured distribution of intensity along the axis normal to a crystal face is compared to that to be expected from a plane piston radiating into a semi-infinite medium, and the agreement shows that the theoretical assumptions are fulfilled for the case used and that the "effective area" of the piston is essentially the actual area of the quartz disc.

Fradkina, E. M.; see Shirokov, M. F., and Fradkina, E. M. (1946)

Fritze, U.; see Meixner, J., and Fritze, U. (1949)

Gassko, R. E.; see Tartakovskii, B. D., and Gassko, R. E. (1949)

Gavreau, V.; see Calaora, A., and Gavreau, V. (1956)

Gazaryan, Yu. L. (1957) WAVEGUIDE PROPAGATION OF SOUND FOR ONE CLASS OF INHOMOGENEOUS LAMELLAR MEDIA. Sov. Phys.-Acoust., 3, 135-149.

An integral representation is found for the field of a spherical harmonic point radiator situated in a medium in which the velocity of sound is varied according to Epstein's law. The case of waveguide propagation is investigated. A solution is found for waveguide propagation in an inhomogeneous semi-space with absolutely reflecting boundaries, for the waveguide axis lying in the semi-space boundary.

Greenblatt, S. (1950) THREE-TRANSDUCER RECIPROCITY FORMULA FOR VIBRATION PICK-UPS. J. Acoust. Soc. Am., 22, 881.

Reference is made to (1) an early paper on reciprocity calibration, where relationships are derived for a procedure using two pick-ups and a vibrator, and (2) a subsequent paper where an alternative method using three pick-ups is derived. Each pick-up in turn is used to drive one of the other two and the input driving current and output voltage are read. In each case the voltage value can be expressed in terms of the current, the blocked force per unit driving current, and the impedances involved. The 6 expressions can be combined to give a formula in which the sensitivity of any one pick-up is expressed in terms of the six voltage and six current values.

Greenspan, M. (1958) DISTRIBUTED TRANSDUCER. J. Acoust. Soc. Am., 30, 528-532.

The distributed transducer is an array of transducers separated by inactive material having their common characteristic impedance, z_0, and terminated in z_0 at one (the absorber) end. The other end radiates into a load. The input voltages at the successive inputs are delayed so that the speed of the electrical wave, traveling in the direction absorber to load, equals the speed of sound in the transducer material. The elements may or may not be identical and they may or may not be operated near resonance; the acoustic waves arrive at the load in phase in any case. A great variety of frequency-response characteristics is readily synthesized; particular attention is paid to a flat response over a very broad range. At the same time, the response at the absorber is subject to some control so that the power there dissipated can be minimized.

Guptill, E. W. (1952) AN EXACT SOLUTION OF THE ACOUSTICAL FIELD NEAR A CIRCULAR TRANSDUCER. J. Acoust. Soc. Am., 24, 784.

The purpose of this letter is to point out that an exact solution for the entire acoustical field of an extended source is possible if the ordinary boundary conditions are only slightly altered.

Guptill, E. W. (1953) THE SOUND FIELD OF A PISTON SOURCE. Can. J. Phys., 31, 393-401.

An exact solution is presented for the sound field between two infinite walls when the source is a piston in one of the walls. A method is also outlined for the case of a source having any amplitude distribution which is a function only of radial distance from the centre of the source. Several graphs are shown and they are intended to illustrate how the pressure on a receiving crystal would vary when the wall separation is changed.

Guptill, E. W., and MacDonald, A. D. (1952) THE ACOUSTICAL FIELD NEAR A CIRCULAR TRANSDUCER. Can. J. Phys., 30, 119-122.

An approximate solution for the near field of a circular transducer is given. The results indicate that, if a similar transducer is used as a receiver, the measured particle velocity is equal to $1 + [2.70/(ka)^2]$ times the plane wave velocity where ka is the number of wavelengths in the perimeter of the transducer.

Harvey, F. K. (1951) A PHOTOGRAPHIC METHOD FOR DISPLAYING SOUND WAVE AND MICROWAVE SPACE PATTERNS. Bell System Tech. J., 30, 564-587.

A probe pick-up scans the sound or microwave field and the amplified probe output controls the brilliance of a small lamp affixed to the probe. A camera set at time exposure records the light intensity variations of the lamp as it moves across the scanned field, forming a pattern on the film of the amplitude distribution. Phase fronts can be delineated by adding a constant amplitude signal to the probe output. Photographs are included which show: sound and microwave patterns of lenses, diffraction at a straight edge and disk, refraction by a prism, diffusion of sound by a divergent lens and radiation from loud speakers. Also, by transposition of source and receiver, directional patterns of transducers acting as microphones are obtained which (by reciprocity) provide a means for examining the directional characteristics of non-reversible transducers such as a carbon microphone. A calibration method is described which allows the relative value of the field intensities to be determined.

Haskell, N. A. (1949) A SUBSTITUTION METHOD FOR THE ABSOLUTE CALIBRATION OF VIBRATION PICK-UPS. Geophysics, 14, 558-561.

By making use of the general relations between input and output currents and voltages in 4 terminal networks of bilateral impedances a relationship is derived between the velocity response of a reversible vibration pick-up and the velocity output of the same device, when used as a source of mechanical vibrations. It is shown that any vibration pick-up may be calibrated in absolute terms as a function of frequency by purely electrical measurements (input current and output voltage) made on the given pick-up, and auxiliary reversible pick-up, and a variable frequency driver.

Heller, G. S.; see Keck, W., Heller, G. S., and Williams, A. O., Jr. (1951)

Hiedemann, E., and Osterhammel, K. (1937) DIRECTIONAL CHARACTERISTICS OF ULTRASONIC SOURCES. Z. Physik, 107, 273-282.

Photographs are reproduced giving the amplitude-fields of quartzes with varying ratio of thickness to ultrasonic wavelengths. It must now be decided, the authors conclude, whether, by comparison of the theoretical formulae for the directional characteristics with those derived from experiment, the thickness of the radiator should not be replaced by a smaller, "effective" thickness, and whether there is a simple relation between these two quantities.

Horton, C. W., and Sobey, A. E., Jr. (1958) STUDIES ON THE NEAR FIELDS OF MONOPOLE AND DIPOLE ACOUSTIC SOURCES. J. Acoust. Soc. Am., 30, 1088-1099.

It is shown that when an observer is not farther than one wavelength from an acoustic source, he can determine the distance to the source from measurements of the pressure and of the particle velocity of the medium. The expressions are developed using integrals of the power so that they are relatively insensitive to the pulse shape. Exact expressions are obtainable only in the case of a monopole source. However, a ratio R_2 is introduced which shows a monotonic dependence on distance in the near field and which is surprisingly insensitive to the nature of the source and to the shape of the wave. Experimental measurements are carried out for a dipole source. Agreement between the theory and the experiment is only moderate because of the difficulty in making sufficiently accurate acoustic measurements.

Ingard, U., and Lamp, G. L., Jr. (1957) EFFECT OF A REFLECTING PLANE ON THE POWER OUTPUT OF SOUND SOURCES. J. Acoust. Soc. Am., 29, 743-744.

The presence of a reflecting plane boundary will affect the power output of a sound source located above it. This effect may be expressed as a "power amplification factor," which was calculated for a number of elementary sound sources (monopole, dipole and longitudinal quadripole) as a function of the distance between the plane and the source. Special attention was given to the evaluation of the source-height-corresponding to minimum power output, and to the ratio between the maximum and minimum power radiated.

Ingard, U., and Pridmore-Brown, D. (1956) SOUND RADIATION FROM THE ACOUSTIC BOUNDARY LAYER. J. Acoust. Soc. Am., 28, 128-129.

The sound radiated from a finite rectangular plate in an infinite wall oscillating in shear motion is calculated. The order of magnitude of the intensity of this sound field is compared with that which is produced when the plane oscillates with the same amplitude in a direction normal to its surface.

Ives, H. E. (1942) PRESSURE OF RADIATION IN MOVING SYSTEM. J. Opt. Soc. Am., 32, 32-34.

The role of radiation pressure in radiation measurements in a moving system is discussed. Both irradiation and radiation pressure are unaffected by motion of the entire system of source and receiver. The investigation confirms the result of Lorentz as to invariance of irradiation in a system of co-moving source and receiver to the first order of v/c, extends it to all orders, and eliminates the variation of radiation pressure with velocity.

Jacobson, M. J. (1957) ANALYSIS OF A MULTIPLE RECEIVER CORRELATION SYSTEM. J. Acoust. Soc. Am., 29, 1342-1347.

A theoretical study is made of an acoustic receiving system which contains a single correlator whose inputs are obtained from arrays of omnidirectional receivers. Mathematical expressions are developed for the mean system output when the input arises from a distant localized signal source. In addition, two major advantages of multiple receiver correlation are discussed in detail. These are improved directional patterns on narrow band signals and increased output signal-noise ratio resulting from the use of more than two receivers.

Jones, R. C. (1945) ON THE THEORY OF THE DIRECTIONAL PATTERNS OF CONTINUOUS SOURCE DISTRIBUTIONS ON A PLANE SURFACE. J. Acoust. Soc. Am., 16, 147-171.

The directional pattern at any distance from an arbitrary continuous distribution of sources is obtained. The approximate relation which holds at large distances is derived, and the simpler formulae which hold when the surface distribution has several different kinds of symmetry are developed. The case is studied in which the sources are distributed along a line. Directional patterns corresponding to specific source distributions are given. Although it is easy to specify a source distribution which will yield any directional pattern satisfying certain mathematical conditions of convergence, such distributions are usually of infinite extent, and therefore do not correspond to distributions of practical interest. A method of attack is suggested for the problem of determining the distribution of specified extent which yields the directional pattern of optimum characteristics for any particular application. Tables of the directional patterns are given.

Kalusche, J. (1950) A LOUDSPEAKER ARRANGEMENT WITH UNILATERAL DIRECTIVITY. Z. angew. Phys., 2, 411-415. (In German)

By combining a first-order transmitter with an acoustic transit-time element, a heart-shaped radiation diagram can be obtained. Curves are given showing the radiation characteristics of a linear arrangement of six such combinations for frequencies of 100, 200, 500, 1000, 3000, and 10,000 c/s and for both the horizontal and the vertical plane. Less than 10% of the sound energy is radiated backwards.

Karnovskii, M. I. (1949) WORK OF SOVIET ACOUSTICAL ENGINEERS IN THE STUDY OF DIRECTIONAL PROPERTIES OF TRANSMITTERS AND RECEIVERS. Izv. Akad. Nauk, SSSR, Ser. Fiz., 13, 698-709. (In Russian)

This paper is an enumeration of results obtained in the investigation of the directionality of various geometrical forms of sound transmitting and receiving surfaces.

Karnovskii, M. I. (1956) CALCULATION OF THE RADIATION RESISTANCE OF CERTAIN DISTRIBUTED SYSTEMS OF RADIATORS. Sov. Phys.-Acoust., 2, 280-293.

This is a theoretical paper. Various arrangements of coherent radiators (spheres) are set up and the active component of the radiation resistance determined.

Keck, W.; see Williams, A. O., Jr., and Keck, W. (1951)

Keck, W., Heller, G. S., and Williams, A. O., Jr. (1951) MEASUREMENTS OF THE UNDERWATER SOUND FIELD GENERATED BY QUARTZ TRANSDUCERS. J. Acoust. Soc. Am., 23, 168-172.

The mean-square pressure distributions in the ultrasonic fields generated in water by quartz transducers of various shapes were presented on an oscilloscope screen and photographed. The beams, pulsed at an audiofrequency, were swept back and forth across a small pressure-sensitive microphone placed at various distances from the source. The pulse envelopes were square-law detected and amplified before presentation. All the transducers were of X-cut quartz, excited near their resonance frequency of about 1 Mc/s. Square pieces with circular and ring-shaped electrodes, as well as circular and ring-shaped pieces, were used; all were about 2 cm in diameter. Comparisons with theory were made for radial and axial mean-square pressure distributions. From study of the axial distributions it was concluded that simple piston theory adequately describes these transducers, provided the baffles and electrodes satisfy certain geometrical conditions. It appears that 18.5° X-cut crystals tend to vibrate over the whole exposed surfaces even outside the electrode regions.

Kendig, P. M., and Mueser, R. E. (1947) A SIMPLIFIED METHOD FOR DETERMINING TRANSDUCER DIRECTIVITY INDEX. J. Acoust. Soc. Am., 19, 691-694.

A system is devised whereby the directivity index of an acoustic transducer may be computed by planimeter measurement of the area under a pattern curve. This is made possible by adjusting the coordinates of a chart so that total power may be measured as area.

Khaskind, M. D. (1957) DIFFRACTION AND RADIATION OF SOUND WAVES IN LIQUIDS AND GASES, I. Sov. Phys.-Acoust., 3, 371-384.

A general theory is presented of the hydrodynamic forces acting on a body during the diffraction and emission of sound waves in liquids and gases. It is shown that the theory developed by the author some time ago (Zh. Eksper. Teor. Fiz., Vol. 16, No. 7, 634-646, 1946) is actually in close agreement with the theory of hydrodynamic forces and moments in the diffraction problem.

Khaskind, M. D. (1958) DIFFRACTION AND RADIATION OF SOUND WAVES IN LIQUIDS AND GASES, II. Sov. Phys.-Acoust., 4, 91-99.

General equations are established in the quadratic approximation for the mean values of hydrodynamic forces and moments acting on a body during diffraction and emission of acoustic waves in liquids and gases. The general results are illustrated by concrete examples.

Klapman, S. J. (1940) INTERACTION IMPEDANCE OF A SYSTEM OF CIRCULAR PISTONS. J. Acoust. Soc. Am., 11, 289-295.

Curves have been calculated for the total radiation resistance and reactance of a single circular piston as a function of frequency when another circular piston is vibrating in the same infinite plane, the distance of separation of the two pistons being a parameter. The curves shown are for equal velocity amplitudes and for phase differences of 0° and 180°. These results enable one to calculate the impedance of a piston when there are present an arbitrary number of pistons in arbitrary phases.

Kuhl, W. (1952) ON THE DIRECTIVITY OF SPHERICAL MICROPHONES. Acustica, 2, 226-231.

The directivity patterns of microphones with circular plane diaphragms on the surface of a sphere have been measured for 10 frequencies and are compared with the directivity patterns of point-like microphones on the surface of a sphere, as computed exactly by Schwarz. The directivity patterns for 2 frequencies have been calculated approximately for the microphone investigated.

It is possible to get exactly the same response for all the angles of incidence by adding the absolute values of the voltages of 2 point-like identical microphones situated on opposite points of a sphere. This does not hold for actual microphones with finite dimensions. Finally the frequency response curve of a microphone without any directivity is calculated, viz., a spherical microphone the diaphragm of which covers the whole surface.

Kuhl, W., Schodder, G. R., and Schroder, F. K. (1954) CONDENSER TRANSMITTERS AND MICROPHONES WITH SOLID DIELECTRIC FOR AIRBORNE ULTRASONICS. Acustica, 4, 519-532.

The development of condenser transmitters and microphones with solid dielectric, which are applicable to high-frequency ultrasonics, is described. Mechanical construction, presumable mode of operation, sensitivity, frequency response, mechanical tuning, directional characteristics, linearity, influence of the electrical bias, and charging phenomena are discussed. Finally, the calibration of the microphones in a free sound field making use of the reciprocity method is described.

Kurtz, A. R.; see McGrath, J. W., and Kurtz, A. R. (1942)

Labory, B., and Laville, G. (1957) A STUDY OF THE ULTRASONIC FIELD IN A LIQUID. Compt. rend. (Paris), 245, 1401-1403. (In French)

Following a method of Fox and Rock (1941), the forces on an aluminum cylinder (2 x 2 mm^2) in a sound field from a quartz transducer operating at 1.1, 3.4, 5.6, or 7 kc/s, were determined. That the radiation patterns only agree with theory near the principal maximum is attributed to non-piston-like movement of the transducer.

Laird, D. T., and Cohen, H. (1952) DIRECTIONALITY PATTERNS FOR ACOUSTIC RADIATION FROM A SOURCE ON A RIGID CYLINDER. J. Acoust. Soc. Am., 24, 46-49.

The directionality patterns produced by an acoustic source located on a rigid cylinder of infinite length have been investigated for the case in which the source strength may be represented as a separable function of azimuth angle and axial dimension. It is observed that the pattern in a plane orthogonal to the axis of the cylinder is independent of the axial distribution of the source, and is, in fact, identical with the pattern given by Morse for a source of infinite axial extent. For the particular case in which the ratio of circumference to wavelength is 14, patterns in this plane have been computed numerically using an IBM card-programmed calculator. Patterns in a plane containing the axis of the cylinder have also been investigated.

Lamb, G. L., Jr.; see Ingard, U., and Lamb, G. L., Jr. (1957)

Lapwood, E. R. (1949) THE DISTURBANCE DUE TO A LINE SOURCE IN A SEMI-INFINITE ELASTIC MEDIUM. Phil. Trans., 841, 63-100.

When a cylindrical pulse is emitted from a line source buried in a semi-infinite homogeneous elastic medium, the subsequent disturbance at any point near the surface is much more complex than for an incident plane pulse. The curvature of the wave-fronts produces diffraction effects, of which the Rayleigh-pulse is the most important. The exact formal solution is given in terms of double integrals. These are evaluated approximately for the case when the depths of source and point of reception are $\ll$ their distance apart, allowing a description of the sequence of pulses which arrive at the point of reception. When that point is at the surface and distant from the epicentre, the disturbance there can be regarded as made up of the following pulses, in order of arrival: (a) for initial P-pulse at source; P-pulse, surface S-pulse and Rayleigh-pulse; (b) for initial S-pulse; surface P-pulse, S-pulse and Rayleigh-pulse. If the initial pulse has the form of a jerk in displacement, the P- and S-pulses arrive as similar jerks, whereas the Rayleigh pulse is blunted, having no definite beginning or end. The surface P-pulse takes a minimum-time path and arrives with a jerk in velocity. The surface S-pulse, on the other hand, is confined to the neighborhood of the surface and arrives as a blunted pulse. Moreover, part of the S-pulse arrives before the time at which it would be expected on geometrical theory. Although derived on very restricting hypotheses, these results may throw some light on seismological problems. In particular, it is shown that when the sharp S-pulse of ray theory is converted by the presence of the surface S-pulse and the spreading of S into a blunted pulse, the duration of this composite pulse is of the same order of magnitude as the observed scatter of readings of Sg and other distortional pulses from near earthquakes.

Laufer, A. R., and Thomas, G. L. (1956) NEW METHOD FOR THE CALIBRATION OF A PLANE HYDROPHONE. J. Acoust. Soc. Am., 28, 951-958.

The high-frequency calibration of a plane disk hydrophone of large diameter by the usual plane-wave reciprocity method is a difficult task requiring a large anechoic tank and precise mechanical alignment gear. A new and absolute calibration technique utilizing the radiation pressure of a standing-wave system is described. The calibration curve of a barium titanate hydrophone of diameter 1.5 in. and of resonant frequency 1.0 Mc/s is represented over the frequency range of 300 to 5000 kc/s.

Laville, V.; see Labory, B., and Laville, V. (1957)

Lax, M., and Feshbach, H. (1947) ON THE RADIATION PROBLEM AT HIGH FREQUENCIES. J. Acoust. Soc. Am., 19, 682-690.

The angular distribution of radiation from a vibrating cylinder of arbitrary cross section is considered in the limit of high frequencies. An inhomogeneous integral equation of the first kind is derived for the distribution, and is solved by the method of steepest descents. The first approximation yields the "geometric optics" result in which every element of the radiator radiates normally to itself. Higher order terms are obtained for the case in which the boundary conditions on the radiator surface vary smoothly. The case of an abrupt change in boundary conditions is also solved and in this paper has a wide range of applicability to problems of radiation and scattering of waves as they occur in field physics.

Lide, E. N.; see Trott, W. J., and Lide, E. N. (1955)

Lucas, R. (1950) ON THE RADIATION PRESSURE OF SPHERICAL WAVES. Compt. rend. (Paris), 230, 2004-2006. (In French)

Most investigations of radiation pressure due to sound waves have hitherto been concerned with plane progressive waves and stationary waves. Unlike these cases, with spherical waves near a small pulsating source the density of the kinetic energy is greater than the density of potential energy. It is shown that the radiation pressure for spherical waves $\delta p = W_p \times (1 + 3d \log V/d \log \rho)$ (where W_p is the mean density of potential energy, V is the velocity of sound and ρ the density of the medium). The numerical factor 3, characterizing the problem of spherical symmetry, is significant, for it is here that the result differs from Brillouin's result for plane stationary waves in which this factor is unity. The difference is in effect very small, for in all practical cases $d \log V/d \log \rho$ is insignificant and $\delta p = W_p$ in all cases.

MacDonald, A. D.; see Guptill, E. W., and MacDonald, A. D. (1952)

Malter, Louis; see Wolff, I., and Malter, L. (1929)

Malter, Louis; see Wolff, I., and Malter, L. (1958)

Markham, J. J. (1953) SECOND-ORDER ACOUSTIC FIELDS: RELATIONS BETWEEN ENERGY AND INTENSITY. Phys. Rev., 89, 972-977.

The effects of the recent change in the expression for the average acoustic energy are considered. In particular, its relation to the modified expression for the acoustic intensity is explored. Use is made of Airy's second-order solution of the field equations. The accepted average energy intensity relation has to be reinterpreted in that only part of the energy travels with the velocity of sound. When a wave is propagated down a tube, it is headed by a region of higher density, while behind this region the average density is decreased. The calculation seems to explain the origin of the new term in the average energy density and to relate it to the radiation pressure.

Mawardi, O. K.; see Ewaskio, C. A., and Mawardi, O. K. (1950)

Mawardi, O. K. (1954) A PHYSICAL APPROACH TO THE GENERALIZED LOUDSPEAKER PROBLEM. J. Acoust. Soc. Am., 26, 1-14.

Most analyses of loudspeaker performances are based primarily on the consideration of details of the electromechanical coupling. This approach has proved too inadequate to handle loudspeaker radiation problems. An attempt has been made to set up a general expression relating the free field sound pressure at a remote point to the electrical signal applied to the loudspeaker terminals. This relation in the form of an integral equation is solved exactly for a loudspeaker of circular shape. By means of the solution of the integral equation it appears possible to apply to this problem methods analogous to circuit analysis techniques which represent the transfer function of the system in terms of its characteristic points in the complex frequency plane.

Mawardi, O. K. (1956) ON RADIATION PRESSURE IN ACOUSTICS. J. Phys. radium, 17, 384-390. (In French)

A critical survey for the development of the concept of radiation pressure is presented. In this survey, first restricted to an ideal inviscid fluid, the tensorial character of the radiation pressure is pointed out and its connection with the flux of momentum associated with the wave is studied. It is also shown that the two common definitions of radiation pressure (Langevin and Rayleigh) are closely related and naturally follow from the above mentioned tensor property. The discussion is then extended to the case for a viscous fluid. The interaction of sound waves and rigid obstacles of simple geometrical shape is also discussed. The radiation pressure on these obstacles is computed for some limiting cases and the relation between the radiation pressure and the scattering cross section for these obstacles is investigated. A review of the better known methods of experimentally measuring the radiation pressure is next given. The comparative merit of these techniques as far as accuracy of measurements is concerned has been examined in the light of the discussion of this paper.

Mayer, N. (1953) THE EVALUATION OF THE DIRECTIONAL CHARACTERISTICS OF SOUND TRANSMITTERS AND RECEIVERS. Funk u. Ton, 7, 398-404. (In German)

The sound distribution in reverberant rooms is influenced by the directional characteristics of the sound transmitter, and the sound picked up by the microphone depends also on its directional properties. The author discusses the relative effects of direct and reflected sound in relation to the directional properties of the transmitter and receiver, and shows how to determine their "direction factors."

McGrath, J. W., and Kurtz, A. R. (1942) ISOLATION OF AN ULTRASONIC CRYSTAL RADIATOR FROM CONDUCTING LIQUIDS. Rev. Sci. Instr., 13, 128-129.

McKinney, C. M.; see Owens, W. R., and McKinney, C. M. (1955)

McKinney, C. M.; see Owens, W. R., and McKinney, C. M. (1957)

McKinney, C. M.; see Mechler, M. V., McKinney, C. M., Anderson, C. D. and Collins, F. A. (1957)

McKinney, C. M., and Anderson, C. D. (1954) EXPERIMENTAL INVESTIGATION OF WEDGE HORNS USED WITH LINE HYDROPHONES. J. Acoust. Soc. Am., 26, 1040-1047.

A study has been made of wedge-shaped horns used in conjunction with line sources. The horns are constructed from aluminum plates covered with cellular rubber. Measurements were made over the frequency range of 60 kc to 150 kc using horn lengths from 3 in. to 15 in. and horn angles up to 90°. Results are given graphically in the form of directivity patterns as well as relative gain in sensitivity and beam widths as a function of the several parameters. At 80-kc beam widths as low as 10° are obtained with at least 40-db suppression of the secondary lobes. The horns are easily fabricated and the beam width and sensitivity of the transducers are easily controlled by varying the horn angle.

McKinney, C. M., and Owens, W. R. (1957) WEDGE-SHAPED ACOUSTIC HORNS FOR UNDERWATER SOUND APPLICATIONS. J. Acoust. Soc. Am., 29, 940-947.

This paper gives the results of an experimental investigation of wedge-shaped acoustic horns used in conjunction with line hydrophones. An earlier study covered the frequency range from 50 kc to 150 kc. The measurements have been extended to a lower value of 10 kc. Characteristic features of the horns are moderate directivity with minor lobes at least 40 db below axial response. The horns, which are constructed from aluminum planes covered with cellular rubber or Corprene, are simple devices and very easy to construct. Some related experiments concerning the basic operations of the horns are described.

Mechler, M. V., McKinney, C. M., Anderson, C. D., and Collins, F. A. (1957) SEVERAL GENERAL PURPOSE TRANSDUCER AND REFLECTOR COMBINATIONS FOR UNDERWATER SOUND WORK. J. Acoust. Soc. Am., 29, 1265A.

Several transducer and reflector combinations are described which are useful over a fairly wide range of frequencies. One form consists of a right-angle conical reflector with a line transducer mounted on the principle axis of the cone. The units described have apertures ranging from 6 in. to 48 in. Frequencies covered are from 25 kc to 0.5 mc. One arrangement allows simultaneous operation of the unit as a projector and as a hydrophone. Another transducer, designed to be used in the fractional megacycle region, uses a conventional parabolic reflector with a probe at the focus. Means are shown for rapidly changing the beam width, shading, and focus. Several other experimental transducers are described briefly. Calibration data in the form of directivity patterns, sensitivity, and impedance are shown.

Meeker, W. F.; see Slaymaker, F. H., Meeker, W. F., and Merrill, L. L. (1946)

Meixner, J., and Fritze, U. (1949) THE SOUND FIELD IN THE VICINITY OF A FREE VIBRATING PISTON DIAPHRAGM. Z. angew. Phys., 1, 535-542. (In German)

The sound distribution has been calculated for various ratios of piston diameter to wavelength, and compared with the sound field due to the same piston source operating in an infinite rigid wall (according to Stenzel). Sound fields of this nature are plotted for the cases ka = 4, 6 and 10. Reference is made to theoretical work of Rayleigh, Stenzel and McLachlan.

Mercier, J. (1954) RADIATION PRESSURE IN FLUIDS. Acustica, 4, 441-446. (In French)

This paper is an account of the different ways of considering radiation pressure and of calculating it. Is it a scalar or vectorial quantity? The author introduces a "radiation vector" equal to the product of excess pressure and velocity of displacement of a section of a plane wave and calculates the pressure of radiation on an obstacle. He extends his calculation to the case of progressive plane waves in an absorbent medium and to that of spherical waves.

Merrill, L. L.; see Slaymaker, F. H., Meeker, W. F., and Merrill, L. L. (1946)

Meyer, E., and Diestel, H. G. (1952) REVERBERATION TESTS WITH DIRECTIVE SOURCES AND RECEIVERS. Acustica, 2, 161-166. (In German)

Using strongly directive sources and receivers, the natural vibrations of the interior of a quadrilateral hall were excited and picked-up. The material whose absorption was to be measured covered one side wall completely. Correct results, in a qualitative sense, were obtained at grazing incidence. The values obtained for normal incidence are independent of the wall surface on which the material is fixed and they agree with values obtained in Kundt's tube. The comparison was made for three materials in the range 500-1000 c/s. Some measurements in the usual manner of the factors for diffuse sound incidence were also obtained for comparison.

Molloy, C. T. (1948) CALCULATION OF THE DIRECTIVITY INDEX FOR VARIOUS TYPES OF RADIATORS. J. Acoust. Soc. Am., 20, 387-405.

The "directivity index" is defined as "the ratio of the total acoustic power output of the radiator to the acoustic power output of a point source producing the same pressure at the same point on the axis." The utility of the directivity index concept is that it permits power calculations to be made for all radiators in the same manner as for point sources. Directivity index formulae, together with graphs covering practical cases, are given for the following types of radiators: (1) General plane piston in infinite baffle; (2) Circular plane piston in infinite baffle; (3) Rectangular plane piston in infinite baffle; (4) Sectorial horn; (5) Multicellular horn; (6) Piston set in sphere.

Motulevich, G. P., and Fabelinskii, I. L. (1957) AN OPTICAL METHOD OF ABSOLUTE CALIBRATION OF ACOUSTIC RADIATORS AT LOW SONIC FREQUENCY. Sov. Phys.-Acoust., 3, 220-222.

In an earlier paper the authors showed how the refractive index varies with density at low acoustic frequency. A tube, the ends of which were closed by optical glass blocks, was filled with a liquid of known refractive index, density and frequency characteristics and the radiator connected to it. The tube dimensions were small compared with the wavelength. The unit was then included in one arm of an optical interferometer, e.g., of the Jamin type. By altering the current or voltage to the radiator in a smooth manner the interference pattern was made to appear and disappear. For the optical path-length changes so caused, and with knowledge of the behavior of the liquid, the acoustic field intensities were calculated, and hence an absolute calibration of the radiator was carried out.

Mueser, R. E.; see Kendig, P. M., and Mueser, R. E. (1947)

Mueser, R. E.; see Reitz, J. R., and Mueser, R. E. (1947)

Mueser, R. E.; see Davids, N., Thurston, E. G., and Mueser, R. E (1952)

Negishi, K.; see Torikai, Y., and Negishi, K. (1955)

Nijboer, B.R.A. (1943) THE DIFFRACTION THEORY OF OPTICAL ABERRATIONS. I. GENERAL DISCUSSION OF THE GEOMETRICAL ABERRATIONS. Physica, 10, 679-692.

The geometric aberrations of an axially symmetric system are treated by a new method. A spherical surface is introduced with its centre at the Gaussian image (at a distance σ from the axis) and passing through the centre of the exit-pupil. The actual wave front deviates by an amount $V(\sigma,r,\phi)$ (the aberration function) from the sphere where r and ϕ are plane polar coordinates upon the latter. V is expanded in terms $r^n \cos m\phi$, whereas the characteristic function analogous to V is usually expanded in terms containing $r^n \cos^m \phi$. A single aberration is now defined by an aberration function $b_{\ell rm}\, \sigma^{2\ell+m}\, r^n \cos m\phi$ and as a result, the discussion of the aberration figures is considerably simplified. A simple classification of image errors of all orders is given, according to which the value of m determines the general type to which a given single aberration belongs. We have spherical aberration, coma and astigmatism for m = 0, 1, and 2, respectively.

Nijboer, B.R.A. (1947) THE DIFFRACTION THEORY OF OPTICAL ABERRATION. II. DIFFRACTION PATTERN IN THE PRESENCE OF SMALL ABERRATIONS. Physica, 13, 605-620.

The diffraction theory for arbitrary aberrations of a symmetrical optical system is developed for the case of small aberration. The aberration function, which measures the deviation of the actual wavefront from a sphere, is expanded in a series of the "circle polynomials" introduced by Zernike. This new expansion appears to have considerable advantages; for instance, the problem of the counterbalancing of aberrations of various orders can be solved completely. Formulae are given, from which the intensity distribution of the diffraction pattern in a receiving plane perpendicular to the principal ray in the neighborhood of the Gaussian image can be numerically determined without much labor. The formulae are applied to the diffraction patterns of astigmatism and coma. The results of the numerical computations are given in diagrams showing the lines of equal intensity.

Oestreicher, H. L. (1957) REPRESENTATION OF THE FIELD OF AN ACOUSTIC SOURCE AS A SERIES OF MULTIPOLE FIELDS. J. Acoust. Soc. Am., 29, 1219-1222.

A representation of the field of a sound source of arbitrary shape and size as a series of multipole fields of increasing order is derived. This series is convergent for sources of any size if the surface is sufficiently regular, but its main advantage is for sources which are small compared to the wavelength. In this case the source has, in general, the directivity pattern of a multipole, the order and strength of which can be determined from the formula. Although the representation is not unique, certain coefficients have physical significance. The presently used definition of "strength of a sound source" is discussed and a modified definition suggested.

Olson, H. F., and Preston, J. (1949) SINGLE ELEMENT UNIDIRECTIONAL MICROPHONE. J. Soc. Motion Picture Engrs., 52, 293-302.

A single-element unidirectional microphone for use in sound motion picture recording has been developed with the following characteristics: single-ribbon type; the back of the ribbon is coupled to a damped folded pipe and an acoustical impedance in the form of an aperture; improved cardioid directional pattern; greater output; reduced wieght; and reduced wind-noise response.

O'Neil, H. T. (1949) THEORY OF FOCUSING RADIATORS. J. Acoust. Soc. Am., 21, 516-526.

An approximate theory has been derived describing part of the sound field due to a concave spherical radiator, vibrating with uniform normal velocity; the radius, a, of the circular boundary is assumed to be $\gg \lambda$, the wavelength and the depth of the concave surface. The theory describes the distribution of pressure, particle velocity, and intensity along the axis of symmetry and in the vicinity of the focal plane, perpendicular to the axis at the center of curvature. It is shown that the ratio of the intensity at the center of curvature to the average intensity at the radiating surface is $\simeq (2\pi h/\lambda)^2$ where h is the depth of the concave surface and λ is the wavelength. This ratio can be made very large by suitable choice of dimensions, and the focusing is then very sharp. The point of greatest intensity is not at the center of curvature but approaches it with increasing $kh = 2\pi h/\lambda$ and the greatest intensity is not much greater than the intensity at the center of curvature except when kh is small. In the central part of the focal plane, at angle θ from the axis, the pressure is approximately $\propto (2/ka \sin \theta) J_1 (ka \sin \theta)$, which is equivalent to the directivity function of a flat circular piston of radius, a, for the region at large distance from the piston. The calculations are in reasonable agreement with Willard's experiment data for a 5 Mc/s concave quartz crystal, when allowance is made for the nonuniform normal velocity of the crystal.

Osterhammel, K.; see Hiedemann, E., and Osterhammel, K. (1937)

Owens, W. R.; see McKinney, C. M., and Owens, W. R. (1957)

Owens, W. R., and McKinney, C. M. (1955) CONICAL HORNS FOR USE IN CONJUNCTION WITH UNDERWATER SOUND TRANSDUCERS. J. Acoust. Soc. Am., 27, 202A.

An experimental investigation has been made using conical horns with barium titanate transducer elements for underwater sound use. The horns were formed from stainless steel and covered with cellular rubber. The dimensions of the horns varied from 28° to 60° flare angles and slant lengths from 7 in. to 22 in. The frequency range investigated was from 10 kc to 100 kc. The directivity patterns indicate strong suppression of secondary lobes with moderate directivity.

Owens, W. R., and McKinney, C. M. (1957) EXPERIMENTAL INVESTIGATION OF CONICAL HORNS USED WITH UNDERWATER SOUND TRANSDUCERS. J. Acoust. Soc. Am., 29, 744-748.

An experimental study has been made of radiation patterns and axial gain in the Fraunhofer region for conical horns used in conjunction with underwater sound transducers. Results of the data are presented in a form that is useful in design of conical horns that have optimum dimensions.

Pachner, J. (1949) PRESSURE DISTRIBUTION IN THE ACOUSTICAL FIELD EXCITED BY A VIBRATING PLATE. J. Acoust. Soc. Am., 21, 617-624.

Pressure distribution in the acoustical field excited by a vibrating circular plate clamped at the edge in an infinite wall is calculated for the points whose distance from the center of the plate is 10-20 times its radius. For completeness a short survey of the theory of forced vibrations of plates is also given.

Pachner, J. (1951) ON THE ACOUSTICAL RADIATION OF AN EMITTER VIBRATING IN AN INFINITE WALL. J. Acoust. Soc. Am., 23, 185-197.

The velocity potential distribution of a circular emitter vibrating in an infinite wall is calculated by the King method for the points immediately before the wall. The close connection is shown between the Rayleigh formula and the expression for the velocity potential expanded in spherical wave functions is transcribed into an abstract form by means of the Dirac bra-vector, kep-vector and linear operator represented by the corresponding matrices. The space distribution of the velocity potential is then computed from the known values in the plane immediately before the emitter by the well-known method of undetermined coefficients written in its matrix form. Thereafter the space distribution of the velocity potential is determined by another, new method due to H. Stenzel. In both methods, explicit expressions are given for the case of a vibrating rigid disk, membrane and plate.

Pachner, J. (1951) ON THE ACOUSTICAL RADIATION OF AN EMITTER VIBRATING FREELY OR IN A WALL OF FINITE DIMENSIONS. J. Acoust. Soc. Am., 23, 198-208.

The field excited by such an emitter is considered as superposed by 2 fields. The first is that where the same emitter is vibrating in an infinite wall and the second that which (a) causes the resultant field in the free part of the plane going through the wall to vanish and (b) has a normal derivature which vanishes on the surface of the emitter and wall. While the first field may be considered as known from other papers, the second is computed from an integral-differential equation that follows from Rayleigh's formula. The equations expressing the velocity potential distribution and those deduced from it are written in an abstract form by means of the Dirac bra-vectors, kep-vectors and linear operators represented by the corresponding matrices. This method may be used for any mode of vibrations of the emitter and for any shape of the wall, but becomes easier if the wall is circular.

Pachner, J. (1951) ON THE ACOUSTICAL RADIATION OF AN EMITTER VIBRATING FREELY OR IN A WALL OF FINITE DIMENSIONS. J. Acoust. Soc. Am., 23, 481.

Pachner, J. (1956) ON THE DEPENDENCE OF DIRECTIVITY PATTERNS ON THE DISTANCE FROM THE EMITTER. J. Acoust. Soc. Am., 28, 86-90.

A method is developed for easily determining the directivity pattern in an arbitrary distance from the emitter from measured instantaneous values of the field in other distance. Numerical computation is facilitated by the tables put together in this paper.

Pachner, J. (1956) INVESTIGATION OF SCALAR WAVE FIELDS BY MEANS OF INSTANTANEOUS DIRECTIVITY PATTERNS. J. Acoust. Soc. Am., 28, 90-92.

A method is proposed for determining the traveling and standing components of an arbitrary scalar wave field from the measured instaneous values of the field on the surface of two spheres surrounding the emitter.

Parker, E. N. (1953) ACOUSTICAL RADIATION FROM THE VELOCITY FIELD IN A COMPRESSIBLE FLUID. Phys. Rev., 90, 240-242.

The problem of computing the radiative portion of a field is considered. By considering the process of emitting radiation, an operational interpretation of the wave equation is developed. This interpretation allows one to write down immediately the inhomogeneous wave equation expressing the radiation from a velocity field in a compressible medium. Guided by the concepts developed in the discussion of the emission of radiation, the inhomogeneous wave equation is deduced from the Navier-Stokes equations. This computation also yields the scattering of the radiative field by the nonradiative flow.

Ponomarev, P. V. (1957) TRANSIENT PROCESSES IN PIEZO-VIBRATORS. Sov. Phys.-Acoust., 3, 260-271.

A quartz plate used as a radiator and also as a receiver is examined for pulses of arbitrary shape. A method is given for evaluating the basic parameters of the vibrator under pulse conditions. The radiated power, input and output impedances and sensitivity of the quartz plate and shown to differ markedly from those under steady-state conditions.

Preston, J.; see Olson, H. F., and Preston, J. (1949)

Pridmore-Brown, D.; see Ingard, U., and Pridmore-Brown, D. (1956)

Primakoff, H. (1944) THE ACOUSTIC PROPERTIES OF DOMES. I. OSRD 3159. Columbia University, Division of War Research, Underwater Sound Reference Laboratories.

For the purpose of providing material of possible assistance in setting up specifications for domes, a critical study is made of existing information both of an experimental and theoretical nature.

The various reports issued by the Underwater Sound Reference Laboratories covering dome tests are evaluated and analyzed theoretically. The detailed theoretical discussion of the acoustic performance of domes, based on the recent fundamental mathematical work performed by the NRDC Applied Mathematics Panel, will be presented in Part II of this study.

As a result of the discussion, it is possible to devise simple approximate relations covering the acoustic performance of domes as a function of:

a) wall thickness of the dome,
b) properties of the material used, especially its density,
c) frequency and directivity of the enclosed transducer,
d) size of the dome relative to that of the transducer; position of transducer in dome, and
e) shape of the dome.

Requirements to be fulfilled in dome design, based on formulae allowing prediction of the magnitude of dome transmission loss and of dome reflections, are also given.

Primakoff, H. (1944) THE ACOUSTIC PROPERTIES OF DOMES. II. OSRD 3372. Columbia University, Division of War Research, Underwater Sound Reference Laboratories.

The report gives the theoretical derivations of the formulae for the transmission loss and specular reflection introduced by domes. The formulae themselves have been extensively discussed and compared with experiment in Part I of this study.

The total sound field pressure of a dome enclosed transducer P is found explicitly by transforming the wave equation satisfied by P, into an inhomogeneous integral equation. The integral equation for P is solved by a method of series expansion in powers of h, the dome wall thickness, yielding successively the "undisturbed" sound field p, and the "first, second, ... m'th, ... order disturbed" sound fields hp_1, h^2p_2, ..., h^mp_m, ... In terms of these,

$$P = p + \sum_{m=1}^{\infty} h^m p_m$$

All the $h^m p_m$ can be expressed in terms of hp_1, which in turn is given as a superposition in the form of an integral over the dome surface, of secondary wavelets with amplitudes proportional to p. This basic integral for hp_1 in terms of p was first obtained by a "limiting" boundary value method, in the recent fundamental mathematical work of the NDRC Applied Mathematics Panel.

The integral giving hp_1 in terms of p is explicitly evaluated in all regions of interest. With hp_1 available, P and, consequently, the magnitudes of transmission loss and specular reflection are found. The angular breadth of the specularly reflected beam is determined. The change in radiation impedance of the transducer due to the dome is estimated and found to be small. A brief discussion is given of domes of special shape, and of the effect of domes on echo-ranging in the vertical plane. Finally, the various physical and mathematical approximations made are discussed and justified.

Primakoff, Henry; see Foldy, Leslie L., and Primakoff, Henry (1945)

Pritchard, Robert L. (1951) DIRECTIVITY OF ACOUSTIC LINEAR POINT ARRAYS. Office of Naval Research, Technical Memorandum 21.

This research deals with a theoretical study of linear arrays of acoustic point elements, with particular emphasis on the broadside array. A systematic method is presented for analyzing the directive properties of arrays with non-uniform excitation of the elements. Steering of the directivity pattern, including the equal-minor-lobe type, is discussed. An improved method of estimating the beam width and a new method of computing the directivity factor to a very good approximation are described. Another type of optimum directivity pattern, different from the equal-minor-lobe type described in an earlier report, has been obtained by requiring that the directivity index be a maximum. For element spacings less than a half-wavelength, these patterns become super-directive. In an effort to evaluate the practicability of using such super-directive arrays, expressions have been derived for the sound-transmission efficiency of the array and for the electric power available in sound reception. The performance of ideal arrays under non-steady-state excitation is also discussed.

Pritchard, R. L. (1951) DISCUSSION OF PAPERS BY PACHNER AND BY STENZEL ON RADIATION FROM A CIRCULAR EMITTER. J. Acoust. Soc. Am., 23, 591.

Pritchard, R. L. (1953) THE DIRECTIVITY OF SPHERICAL MICROPHONES. Acustica, 3, 359-362.

By employing the reciprocity principle, alternative solutions for the response of spherical microphones considered recently by W. Kuhl are given in terms of the response for sound emission. An existing solution for the sound field radiated from a vibrating spherical cap is used to calculate the directional response of a cylindrical microphone mounted in a sphere. Similarly, the frequency response of a completely spherical (nondirectional) microphone is calculated with the help of the electroacoustic reciprocity theorem. Results of numerical computations for each type of calculation are given and are compared with Kuhl's results, which were obtained by direct integration of the sound pressure over the active surface of the sphere.

Pritchard, R. L. (1953) OPTIMUM DIRECTIVITY PATTERNS FOR LINEAR POINT ARRAYS. J. Acoust. Soc. Am., 25, 879-891.

The sharpest major lobe of a directivity pattern due to a linear array of equally spaced point elements is achieved when the elements are excited in such a manner that all minor lobes in the pattern have the same relative amplitude. Methods of producing such equal-minor-lobe patterns were originally given in the radio literature by Dolph and by Riblet and are summarized briefly in this paper. In particular, the synthesis method indicated by Riblet is described in general terms, and the effect of the element spacing is discussed in detail. Included in this discussion is the subject of super-directivity. Results of numerical calculations based on these methods are presented as families of curves showing the relationships existing among angular width of the major lobe, relative amplitude of the equal minor lobes, directivity index, and number and spacing of the elements in the array for 5-13 odd numbers of elements. In addition, the synthesis methods are extended to compensated, or steered, arrays.

Pritchard, R. L. (1953) APPROXIMATE CALCULATION OF THE DIRECTIVITY FACTOR OF LINEAR POINT ARRAYS. J. Acoust. Soc. Am., 25, 1010-1011.

An approximate method of calculation is developed in which the reciprocal of the directivity factor of a linear array of equi-spaced point elements is interpreted as an area beneath the curve of the square of the directional characteristic (relative sound pressure at a large fixed distance) expressed as a function of an auxiliary variable. Data required for the approximate calculation are the spacing between the elements of the array, their relative excitation, the beam width of the pattern, and the value of the average amplitude of the minor lobes of the pattern. The utility of the method is illustrated by a numerical example: a broadside array of 13 uniformly excited elements with a relative spacing of $d/\lambda = 7/8$. The directivity index obtained by the approximate method described agrees within 0.3 db of the exact value.

Pritchard, R. L. (1954) MAXIMUM DIRECTIVITY INDEX OF A LINEAR POINT ARRAY. J. Acoust. Soc. Am., 26, 1034-1039.

The maximum directivity index of a symmetrical, linear point array has been calculated as a function of the number and spacing of the elements in the array.

The excitation required to produce a maximum directivity index is not uniform, except for integral-half-wavelength element spacings, and in general the minor lobes of the directional response patterns produced are not of equal, nor of small, amplitude. For element spacings exceeding a half-wavelength, a conventional type of pattern and of excitation is found to produce the maximum directivity index. On the other hand, as the element spacing is reduced below a half-wavelength, the directivity patterns corresponding to the maximum directivity index become superdirective, and the directivity index may be improved relative to the value obtainable with uniform excitation. However, this improvement is obtained only at the expense of requiring large, reversed-phase excitation. Numerical results are presented for 3-, 5- and 7-element arrays.

Raes, A. C. (1954) CHARACTERISTIC CURVES OF THE DIRECTIVITY OF ELECTRO-ACOUSTIC TRANSDUCERS. Ann. Telecomm., 9, 313-314. (In French)

An experimental method is described which does not require the use of an acoustic room. The loudspeaker on test is energized by sound which reaches its maximum intensity sufficiently rapidly (within 5 msec), that it can be registered by a detecting microphone near the loudspeaker before any reflected waves from the walls of the room reach the microphone. Results are given of tests which agree reasonably with the calculated values.

Reitz, J. R., and Mueser, R. E. (1947) TWO PARABOLIC REFLECTOR UNDERWATER TRANSDUCERS. J. Acoust. Soc. Am., 19, 35-43.

A line source underwater transducer may be used in conjunction with a parabolic cylinder reflector to produce a highly directive sound ray similar to that obtained from a shaded plane source. Poor patterns result from the construction of a unit where the element is at the focus of a parabolic cylinder reflector because the finite size of the element is so great as to block many of the reflected sound rays. To overcome this difficulty an ideal surface is derived which permits the line source to be placed out of the direct path of the reflected rays. This derivation and the construction and acoustic characteristic of the consequent transducer are discussed.

Rhian, E. (1954) AN EXACT METHOD FOR DETERMINING THE DIRECTIVITY INDEX OF A GENERAL THREE-DIMENSIONAL ARRAY. J. Acoust. Soc. Am., 26, 704-706.

An exact method for determining the directivity index of a general three-dimensional array with phased elements is described. The expression for the reciprocal of the directivity factor is shown to be a sum of terms which are simple functions of the sensitivity, phasing, and location of the elements of the array. As an example, the method is applied to a 16-element plane array.

Rock, G. D.; see Fox, F. E., and Rock, G. D. (1938)

Rudnick, I., and Stein, M. N. (1948) RECIPROCITY FREE FIELD CALIBRATION OF MICROPHONES TO 100 KC IN AIR. J. Acoust. Soc. Am., 20, 818-825.

A procedure for obtaining a free field reciprocity calibration of a W. E. 640 AA transducer in the frequency range 1-100 kc/s is described. The basis for the calibration is investigated in some detail, particularly with regard to (a) the validity of electro-acoustic reciprocity relations applying to the transducer and (b) the nature of the acoustic calibrating field. The transducers were found to be reciprocal. Factors affecting the acoustic field are the degree of approximation of the source to a point transducer, the effect of walls of the anechoic room, and the attenuation in the air. It is shown that when the separation of the transducers used in these measurements is 30 cm, the transducers are essentially points; the room produces very little effect, but the attenuation in the air can produce a significant error at high frequencies unless correction is made for it. The results of the calibration of two W. E. 640 AA transducers are presented, giving their responses as speakers and microphones, the latter with and without a protective grid.

Rzevkin, S. N. (1937) WAVE FIELD OF A PIEZO-QUARTZ RADIATOR. Compt. Rend. (USSR), 16, 267-270. (In English)

Stroboscopic examination of the pattern of the ultrasonic waves radiated from quartz plates immersed in oil.

Rzhevkin, S. N. (1949) ENERGY MOVEMENT IN THE FIELD OF A SPHERICAL SOUND RADIATOR. J. Tech. Phys., USSR, 19, 1380-1396. (In Russian)

A generalized expression is given for the acoustic field of a composite spherical sound radiator, involving spherical Bessel and Neumann functions. The connection is shown between the conventional Stokes-Rayleigh functions $f(jkr)$ and $F(jkr)$ and the new, more convenient functions $\delta(kr)$, $G(kr)$, $D(kr)$ and $\epsilon(kr)$. The problem of the energy fluxes is investigated and it is established that in the field of simple radiators tangential energy currents are absent, whereas they are always present with composite radiators. As an example, the field of the radiator of order (0 + 1) is analyzed in detail, general expressions being obtained for the "additive energy" and "additive mass" of zonal and sectorial radiators of any order.

Sabin, G. A. (1956) TRANSDUCER CALIBRATION BY IMPEDANCE MEASUREMENTS. J. Acoust. Soc. Am. 28, 705-710.

A self-reciprocity free-field response calibration of a resonant electroacoustic transducer may be determined in a small water-filled tank by only two electrical impedance measurements at each discrete frequency point. The use of a pulse technique permits the measurement of electric impedance under two conditions: (1) in a free field and (2) under the influence of a totally reflected signal. The vector difference between these two impedances together with the reciprocity parameter (j) establish the free-field response. No measurement of voltage, current, or power is required; the ratio of the hydrophone voltage to the projector current is measured as an impedance vector. This method is particularly applicable in the ultrasonic frequency range.

Sacerdote, C. B.; see Sacerdote, G., and Sacerdote, C. B. (1956)

Sacerdote, G. (1939) DENSITY OF ENERGY IN ACOUSTIC PROBLEMS. Pont. Acad. Sci., Acta, 3, 47-52.

In many acoustical problems, particularly those of the distribution of sonorous energy and of the course of the sound wave in a definite medium the density of energy is taken as fundamental parameter. In fact the analytical expression of such phenomena as function of the density of energy has a simpler form than when presented as function of the pressure. The density of energy may be considered as a parameter to be considered by itself. This density is defined as follows: $E = 1/2\ (\rho\ V^2 + P^2/\rho c^2)$ and is the sum of the kinetic and potential energies per unit of volume: ρ = density of medium, c = velocity of sound, V = velocity of displacement, P = sonorous pressure. After treating the general equations of propagation the author deals with certain applications to architectural acoustics which become more simple by means of this method.

Sacerdote, G., and Sacerdote, C. B. (1956) A METHOD FOR THE MEASUREMENT OF THE DIRECTIVITY FACTOR. Acustica, 6, 45-48.

An electromechanical apparatus for the direct determination of the directivity factor of a loudspeaker can be employed to determine, in a very short time, its characteristics of directivity as a function of frequency.

Schelkunoff, S. A. (1943) A MATHEMATICAL THEORY OF LINEAR ARRAYS. Bell System Tech. J., 22, 80-107.

A mathematical theory, suitable for appraising and controlling directive properties of linear antenna arrays, can be based upon a simple modification of the usual expression for the radiation intensity of a system of radiation sources. The first step in this modification is closely analogous to the passage from the representation of instantaneous values of harmonically varying quantities by real numbers to a symbolic representation of these quantities by complex numbers. The second step consists in a substitution which identifies the radiation intensity with the norm of a polynomial in a complex variable. The complex variable itself represents a typical direction in space. This mathematical device permits tapping the resources of algebra and leads to a pictorial representation of the radiation intensity.

Shirokov, M. F., and Fradkina, E. M. (1946) THE ENERGY EQUATION IN ACOUSTICS OF MOVING MEDIA AND SOME OF ITS APPLICATIONS. Compt. Rend. (USSR), 52, 29-32.

The energy equation is set up and applied to the sound field acting upon a moving sound receiver (e.g., one exposed to a wind or connected to an aircraft). A formula is deduced for the sound intensity registered by the receiver and a polar diagram of the distribution of sound intensity in the space surrounding the source is constructed. A general formula for the doppler effect is established.

Simmons, B. D., and Urick, R. J. (1949) THE PLANE WAVE RECIPROCITY PARAMETER AND ITS APPLICATION TO THE CALIBRATION OF ELECTROACOUSTIC TRANSDUCERS AT CLOSE DISTANCES. J. Acoust. Soc. Am., 21, 633-635.

The reciprocity parameter for a plane wave sound field is shown to be equal to $2A/\rho c$, where A is the area of the plane piston source and ρc the characteristic acoustic resistance of the medium. It is shown experimentally that the sound field in front of a plane piston source is effectively plane over a distance $\simeq A/\lambda$, and that in such a region the plane wave parameter may be used to obtain a free field calibration of the transducer by the reciprocity method.

Skudrzyk, E. (1951) THE CONSTRUCTION OF EFFICIENT ULTRASONIC RADIATORS. Electrotech. u. Maschinenb., 68, 173-178. (In German)

The piezo-electric effect is briefly described and minute details given for the chemical silvering of quartz surfaces. It is pointed out that such a method of applying voltage to a crystal is only satisfactory for low powers. Requirements of a high-power mount are considered, one-sided radiation and provision for uniform heating being stressed. Drawings are given of mounts developed both commercially and by the author for intensities up to 40 W/cm^2. Special attention is given to a totally enclosed radiator for medical purposes in which the output is taken through a thin duralumin membrane. In this connection the problem of concentration of the radiation is studied. Preferred methods of irradiating fluids are described. A simple statement is made of the electromechanical theory of the transducer.

Skudrzyk, E. (1951) THE CONSTRUCTION OF EFFICIENT ULTRASONIC RADIATORS, II. Elektrotech. u. Maschinenb., 68, 202-212. (In German)

The idea of mechanical impedance is introduced and expressions given for equivalent mass and stiffness. Losses in the quartz are represented by a simple resistance. An example is given of the calculation of the equivalent circuit and radiated power of a crystal. An introduction is given to the more accurate theory of quartz resonators and in particular it is shown how the simple equivalent circuit must be modified to take this into account. The magnetostrictive oscillator is treated in a similar way to the quartz and numerical examples given. Finally the problem of measuring the radiated power is studied. These include: direct measurement of the radiation pressure, heating effect in an oil-bath, and in the case of quartz radiators, the measurement of the voltage across the resonator.

Skudrzyk, E. (1958) SOUND RADIATION OF A SYSTEM WITH A FINITE OR AN INFINITE NUMBER OF RESONANCES. J. Acoust. Soc. Am., 30, 1152-1158.

The sound field generated by a composite vibrator consists of a wattless near field, that decreases very rapidly with distance, and an energy-carrying radiation field. For radiators more than half a wavelength apart, the sound fields are spatially incoherent. The radiation field of a complex sound generator can therefore be computed by adding up the energy contributions of its various radiating elements. The radiating elements can be grouped as vibrators that are small in comparison to the wavelength, vibrators without nodal lines that are large in comparison to the wavelength, and vibrators with a nodal line pattern.

The radiation resistance of vibrators without nodal lines can, for most practical purposes, be stated with sufficient accuracy in terms of that of the equivalent sphere. The sound radiation of vibrators with nodal lines can be attributed to two causes. For the low-order modes of vibration, the contributions of the zone of positive and negative amplitude do not compensate one another entirely, and the radiation resistance, though small, is different from 0. Such modes may therefore be expected to contribute to the sound pressure if they are excited in their resonance range. For the high-order modes compensation is complete, but a point force or a force distribution along a line or over a finite area also excites to forced vibrations many low-order modes with very few nodal lines. Since the distance between the nodal lines is greater than the acoustic wavelength in the surrounding medium, the radiation impedance for these modes is very nearly equal to ρc. Since these modes are forced to vibrate at frequencies above their resonant frequency, the resistive component of their impedance being negligible in comparison to the reactive component, this sound pressure is independent of the damping of the system. The radiation impedance is computed for the cases mentioned.

Slaymaker, F. H., Meeker, W. F., and Merrill, L. L. (1946) THE DIRECTIONAL CHARACTERISTICS OF A FREE-EDGE DISK MOUNTED IN A FLAT BAFFLE OR IN A PARABOLIC HORN. J. Acoust. Soc. Am., 18, 355-370.

To obtain a sharp supersonic beam with a parabolic horn, it was found desirable for the diaphragm feeding the horn to radiate most of its energy towards the walls of the horn rather than the mouth. This was done most effectively by a diaphragm vibrating with two concentric circular nodes. An analysis is given of the vibration conditions and radiation diagrams of free-edge diaphragms with 1, 2 or 3 circular nodes, and disk diameters and thicknesses can be calculated to give any desired pattern at any frequency. Following these calculations, a 1-circle node diaphragm was made which gave a satisfactory directional diagram.

Sobey, A. E., Jr.; see Horton, C. W., and Sobey, A. E., Jr. (1958)

Southworth, G. C. (1931) CERTAIN FACTORS AFFECTING THE GAIN OF DIRECTIVE ANTENNAS. Bell System Tech. J., 10, 63-95.

This paper analyzes the performance of antenna arrays as influenced by certain variables within the control of the designing engineer. It starts with an extremely simple analysis of the interfering effects produced by 2 sources of waves of the same amplitude. This is followed by a short discussion of a paper by Ronald Foster, which considers 2 antennas and also 16 antennas when arranged in linear array. Two antennas, separated in space by 1/4 wavelength and in phase by 1/4 period, give sensibly more radiation in one direction than in the opposite. This, for convenience, has been called a uni-directional couplet. A number of these couplets may be arranged in linear array, thereby gaining an extremely useful directive system. Diagrams are shown for such arrays as affected by the number and spacings of the individual couplets. The gains from such arrays are calculated and data are given showing fair agreement between calculation and observation.

Directional diagrams for arrays of coaxial antennas indicate that somewhat less gain may be expected from this form than when the elements are spaced laterally. Combinations of these two types of arrays give marked directional properties in both their horizontal and vertical planes of reference. This principle has been used rather generally in short-wave communication. This paper also discusses effects resulting from combining two or more arrays. In one case the space between 2 arrays tends to emphasize spurious lobes. The directional diagram of such a combination may be rotated within limits by changing the phasing between adjacent arrays or sections of an array. In all of the above cases the influence of the earth is ignored.

A mathematical appendix gives general equations for calculating directional diagrams of linear arrays. Special cases of these equations apply to the figures included in the main part of the test. General equations are also given for calculating the gains of arrays. Similar equations permit the areas of diagrams to be calculated. An extended bibliography on antenna arrays is appended.

Stein, M. N.; see Rudnick, I., and Stein, M. N. (1948)

Stenzel, H. (1952) REMARKS ON A PAPER ENTITLED "CALCULATION OF THE DIRECTIVITY INDEX OF VARIOUS TYPES OF RADIATORS." J. Acoust. Soc. Am., 24, 417-418.

Criticisms are made of the paper by Molloy. Some errors are pointed out, and a different approximation in the solution of the directivity index calculation is claimed to give more accurate results.

Stenzel, H. (1958) Introduction to the Calculation of Sound Phenomena (Sound Fields of Radiators, Piston Diaphragms, Spheres, Etc.) Second revised edition by O. Brosze, Berlin, Springer Verlag. (In German)

Brosze points out that a description of sound phenomena is not completed solely by a statement of mathematical formulae, but requires in addition graphical illustrations and detailed examples. The purpose of the second edition has been to include an extensive survey of the sound fields of piston-diaphragms and spherical sound-transmitters. The book is mainly theoretical and contains numerous diagrams illustrating the pressure amplitude and phase distributions in the sound-fields around various sound sources and obstacles. It contains also a number of useful mathematical tables and a list of references.

Swanson, G. W., Jr., and Thomson, W. T. (1950) THE DESIGN OF RESONANT QUARTZ-CRYSTAL ULTRASONIC TRANSDUCERS FOR RESEARCH PURPOSES. J. Appl. Mech., 17, 427-430.

The paper is intended to co-ordinate the several approaches to the design problem and to present a practical method for designing quartz-crystal transducers for ultrasonic frequencies.

Takeuchi, R. (1950) THE DIRECTIONAL CHARACTERISTICS OF CONICAL REFLECTORS. Memoirs of the Research Institute of Acoustical Science, Osaka National University, 1, 33-37.

The directional properties of a ringstack projector mounted coaxially with a conical reflector are calculated in terms of a convergent series on the assumption that the whole surface of the ringstack vibrates with the same amplitude and phase.

Tartakovskii, B. D., and Gassko, R. E. (1949) DISTRIBUTED SOUND SOURCE SYSTEMS. Izv. Akad. Nauk, SSSR, Ser. Fiz., 13, 654-661. (In Russian)

Discussion of advantages of the distributed over the centralized loudspeaker system.

Thiessen, G. J. (1955) ON THE EFFICIENCY OF AN ACOUSTIC LINE SOURCE WITH PROGRESSIVE PHASE SHIFT. Can. J. Phys., 33, 618-621.

The introduction of a small continuous phase shift along the length of finite line source does not result in a decrease of energy radiated but simply causes the directionality pattern to change. When the phase shift is such that it corresponds to the phase shift with distance on a sound wave, then the directionality pattern has changed through 90° and the energy radiated begins to drop rapidly. At this point the slope of the curve of energy versus phase shift parameter increases with increasing frequency.

Thiessen, G. J.; see Embleton, T.F.W., and Thiessen, G. J. (1958)

Thomas, G. L.; see Laufer, A. R., and Thomas, G. L. (1956)

Thompson, S. P. (1949) THEORETICAL ASPECTS OF THE RECIPROCITY CALIBRATION OF ELECTROMECHANICAL TRANSDUCERS. J. Acoust. Soc. Am., 21, 538-542.

A unified theory of the reciprocity calibration of electromechanical transducers is presented in a form which facilitates the derivation of particular calibration theories. The theories of two types of calibration procedure are treated as special cases. One of the theories is shown to reduce, when lumped standards are used, to that of the original technique of Trent; the other is descriptive of a new procedure. The application of calibration theories is discussed, particular attention being devoted to the use of distributed-constant standards and the consequent difficulties involved.

Thompson, W. T.; see Swanson, G. W., Jr., and Thompson, W. T. (1950)

Thurston, E. G.; see Davids, N., Thurston, E. G., and Mueser, R. E. (1952)

Torikai, Y., and Negishi, K. (1955) A SIMPLE METHOD FOR THE VISUALIZATION OF ULTRASONIC FIELDS. J. Phys. Soc. Japan, 10, 1110.

The method requires no special material except ordinary photographic paper and developer. A transducer is set in a tank filled with dilute developer and a sheet of uniformly exposed photographic paper is irradiated ultrasonically. Patterns appear on the paper as a result of the accelerated development depending on the intensity distribution of the field. Sample results are shown.

Toulis, W. J. (1957) RADIATION LOAD ON ARRAYS OF SMALL PISTONS. J. Acoust. Soc. Am., 29, 346-348.

The radiation load on a piston in an array is examined, preliminarily, through the correspondence of a piston in an infinitely long tube and in a conical horn to arrays on an infinite plane surface and on a rigid sphere, respectively. The evaluation of the velocity potential for the 2 arrays suggests that the average radiation load on an array consists of 2 terms. The principal term arises from a uniform distribution of the total source strength over both active and inactive areas of the array. The secondary term corresponds to the free space for one of the pistons but reduced in magnitude by a factor proportional to the average separation between adjacent pistons.

Trott, W. J., and Lide, E. N. (1955) TWO-PROJECTOR NULL METHOD FOR CALIBRATION OF HYDROPHONES AT LOW AUDIO AND INFRASONIC FREQUENCIES. J. Acoust. Soc. Am., 27, 951-956.

Theory and procedure are presented on an absolute method for calibration of hydrophones in a closed water-filled tank. Unlike other absolute methods at present in use, it depends on a factor that is independent of frequency and is easily measured statically. This factor (0.1 Bl/area) plus voltage and current measurements yields the hydrophone free-field receiving response. The apparatus includes a displacement detecting circuit on one projector, and a means of changing phase and amplitude of the electrical current driving one projector relative to the current driving the second projector. The method has been used over the frequency range from 0.1 to 500 c/s with an accuracy in response measurement better than ± 1/2 db.

Tucker, D. G. (1957) ARRAYS WITH CONSTANT BEAM-WIDTH OVER A WIDE FREQUENCY RANGE. Nature, 180, 496-497.

In underwater sound-ranging systems hydrophones usually have to be used omnidirectionally because otherwise their beam-width would be inversely proportional to frequency. A solution to the problem of providing directional receivers with a constant effective beam-width over a specified range of frequencies is proposed. Directionality is achieved in all planes using a strip (or line) transducer by coupling with delay lines to produce suitable combinations of (sin x)/x patterns from each elementary transducer in the strip. For a frequency ratio of 2r + 1 there must be 2r + 1 elementary transducers and r delay lines. A typical response curve and schematic diagram for a 19-element array are shown. The method is considered applicable to other listening systems and probably for radio aerial systems as well.

Tucker, D. G. (1958) THE SIGNAL/NOISE PERFORMANCE OF ELECTRO-ACOUSTIC STRIP ARRAYS. Acustica, 8, 53-62.

The directional patterns (or directivity curves) and the signal/noise performance of 14 different arrangements of a strip array are discussed and tabulated. The 14 arrangements include 5 used for the determination of the direction of a received signal by a null method. The noise concerned includes the thermal-agitation noise of the array, the noise generated in the receiving amplifiers, and to a large extent also noise arising in the medium of transmission.

Tucker, D. G. (1958) SIGNAL/NOISE PERFORMANCE OF SUPER-DIRECTIVE ARRAYS. Acustica, 8, 112-116.

A super-directive array is defined as one whose effective aperture exceeds its physical aperture, and it is shown that while such an array has a Directivity Index somewhat better than that of an ordinary array, nevertheless its Noise Factor is much worse. Consequently, in many receiving systems, the use of superdirectivity is extended to bearing-determining arrays which give a null response on the axis, and it is shown that the same disadvantage of a bad Noise Factor applies to them also.

Urick, R. J.; see Simmons, B. D., and Urick, R. J. (1949)

Walters, A. G. (1951) ON THE PROPAGATION OF DISTURBANCES FROM MOVING SOURCES. Proc. Cambridge Phil. Soc., 47, 109-126.

The concept of the Green's vibrational function given earlier [Walters, ibid., 45, 69-80 (1949)] is used to obtain a general expression for the disturbance from a point source. The potential due to transient sources of sound moving with subsonic source differs from that for a subsonic source. In the former case it is found that 2 frequencies are heard simultaneously from a source emitting a note of one frequency. The theory is applied to determine some solutions of the 2-dimensional equation of supersonic, irrotational compressible flow, corresponding to the flow around an aerofoil taking into consideration the entropy changes at the shock wave.

Wathen-Dunn, W. (1949) ON THE RECIPROCITY FREE-FIELD CALIBRATION OF MICROPHONES. J. Acoust. Soc. Am., 21, 542-546.

The physical conditions for a valid reciprocity free-field calibration are examined in detail. The expression for the absolute value of the reciprocity parameter J is derived in a general manner. The result shows that J is actually a transfer admittance relating the volume current Q of the linear, reversible transducer to the pressure P this unit causes at a certain point in space. The usefulness of this concept in other than free-field conditions is pointed out. The formula for the sensitivity of the unknown microphone is derived by a method which emphasizes the significance of the physical arrangement, and the limiting conditions are stated. Practical methods for determining the validity of the calibration are suggested.

Welkowitz, W. (1953) CRYSTAL ACOUSTIC ARRAYS. J. Acoust. Soc. Am., 25, 336-337.

A point source method for rapid design of a crystal transducer array using 3 crystal thicknesses in the ratio of 1:2:4 has been developed. Formulae are presented for main lobe width and ratio of secondary lobe amplitude to main lobe amplitude. For a 10 x 10 array (100 elements) this method of design leads to a relative side lobe level of 22 db as compared to a value for a uniform array of 13.4 db at the expense of having a beam-width 1.25 times as wide as the uniform array.

Welkowitz, W. (1956) DIRECTIONAL CIRCULAR ARRAYS OF POINT SOURCES. J. Acoust. Soc. Am., 28, 362-366.

Linear arrays of acoustic and electromagnetic point sources suffer from certain drawbacks. In a plane through the array they produce a bidirectional rather than a unidirectional pattern, and the main lobe width of the optimum pattern varies as the beam is rotated electrically. Circular point source arrays are free from these drawbacks. Author develops theory of circular arrays. The effect of diameter and number of sources is illustrated quantitatively.

Wertz, F. D.; see Camp, L., and Wertz, F. D. (1949)

White, J. E. (1950) A METHOD FOR MEASURING SOURCE IMPEDANCE AND TUBE ATTENUATION. J. Acoust. Soc. Am., 22, 565-567.

If the active face, or acoustic output terminal, of a sinusoidal sound source moves as a plane piston, then the source can be characterized by a blocked pressure and an acoustic output impedance. If this piston is coupled to a microphone by means of a closed air column, the pressure at the microphone depends on the acoustic impedance of the microphone, on the impedance of the source, and on the air column. An expression for this pressure as a function of the length of the air column is developed, and data are presented which show how source impedance, tube attenuation and other quantities may be obtained.

Williams, A. O., Jr.; see Carter, A. H., and Williams, A. O., Jr. (1951)

Williams, A. O., Jr.; see Keck, W., Hiller, G. S., and Williams, A. O., Jr. (1951)

Williams, A. O. (1951) THE PISTON SOURCE AT HIGH FREQUENCIES. J. Acoust. Soc. Am., 23, 1-6.

For a circular plane piston of radius a, producing an ultrasonic beam with propagation constant k (or $2\pi/\lambda$), an expression is derived for the velocity potential or the acoustic pressure, averaged with respect to magnitude and phase over a "measurement circle" equal in area to the piston and centered in the beam. The expression should be highly accurate for $ka \geq 100$, at distances z from the source governed by $(z/a)^3 \geq ka$. It agrees well with results computed, in another way, by Huntington, Emslie and Hugles. The assumption that relatively near the source there is a collimated beam of plane waves is shown not to be very accurate; the averaged pressure falls off monotonically over all distances considered. The velocity potential at the rim of the "measurement circle" is also computed, and compared with the plane wave assumption.

Williams, A. O., Jr., and Keck, W. (1951) EFFECTS OF REFLECTED SIGNALS AND ELECTRIC PICK-UP AT AN ULTRASONIC MICROPHONE. J. Acoust. Soc. Am., 23, 173-175.

When a small microphone is used in an ultrasonic beam, the direct acoustic signal is mixed with electric pick-up and reflected signals. The use of pulses may not entirely remove these interferences. The mixing process is analyzed here for a particular situation and experimental evidence is adduced to support these conclusions: (1) that the main response pattern of the microphone shows space variations of both half the acoustic wavelength and the full wavelength; (2) that the former variation dies out at sufficiently great distances from the source at a rate showing that a single echo path (source-microphone-source-microphone) is responsible along with a constant electric signal; and (3) that the 3 signals can be resolved analytically.

Wilson, H. A. (1920) THE THEORY OF RECEIVERS FOR SOUND IN WATER. Phys. Rev., 15, 178-205.

Sound receivers in water and their mathematical theory are considered in this paper. (1) Single receivers. After proving that a receiver must have small volume to be efficient, the author considers in detail the case of a small spherical receiver connected to the ear by a cylindrical tube. Its resonance frequency is independent of the size of the tube and depends only on the elasticity of the receiver and its effective mass. The sharpness of resonance, however, is greater for larger tubes and for smaller surfaces. The energy transmitted for a given pitch is a maximum for a certain tube size; and while it is independent of the surface at the resonance frequency, for lower pitches the intensity increases with the surface. It is shown that a resonating receiver with a properly chosen tube may concentrate into the tube energy from an area about 850 times the cross section of the tube. The theory agrees with experimental facts and leads to practical suggestions for the design of efficient receivers. (2) Two receivers as used for direction finding. A pair of receivers mounted on a horizontal rod which may be rotated about a vertical axis is an efficient device for getting the direction of a source of sound since it makes use of the binaural effect. The equations for the energy in each tube and for the difference in phase are derived. Unless the separation is very small, the conditions for correct direction finding are always satisfied. The best distance apart is half the wavelength in water for the resonance frequency of the receivers. (3) Multiple receivers. If n receivers are each connected by a tube with a cross section α to a tube whose cross section is $n\alpha$, and if the lengths are such that all the sounds meet in phase, practically all the sound may be concentrated in a single tube. Equations are derived for the case of symmetrically arranged receivers, all equidistant from the source of sound. Except at the resonance frequency, the multiple receivers should be, in practice, more sensitive than any single receiver. (4) Lines of receivers. By a special compensating device the sound from such a set may be concentrated in a single tube. Equations are derived for the energy transmitted in this case. (5) Receivers distributed over large areas. With flexible diaphragms, complete transmission may be secured if the ratio of the tube section to the diaphragm area is properly chosen. With stiff diaphragms, this is approximately true only for the resonance frequency of the receivers. Finally, the conditions for complete transmission for a given frequency are determined for the case of small receivers mounted in a plane in front of a totally reflecting parallel surface.

Wolff, I., and Malter, L. (1929) SOUND RADIATION FROM A SYSTEM OF VIBRATING CIRCULAR DIAPHRAGMS. Phys. Rev., 33, 1061-1065.

From the expression for the velocity potential due to a point source radiating into a semi-infinite medium Lord Rayleigh has determined the sound radiation from a vibrating circular diaphragm in an infinite wall. With the same method, the radiation due to any shaped diaphragm or combinations of diaphragms can be determined. Curves are given for circular diaphragms which show the distribution of pressure over the surface bounding the semi-infinite medium. These curves enable the determination of the radiation from any combination of vibrating circular diaphragms placed in the surface. Calculations have been carried out for a number of special cases. At low frequencies the diaphragms react upon each other to increase the efficiency of radiation. This effect vanishes at high frequencies. The mutual aid of the diaphragms decreases very rapidly as the diatance between the diaphragms is decreased. In certain cases the combination may result in decreased efficiency over particular frequency ranges. These results are all explainable on the basis of phase differences between motion of a diaphragms and the pressure over the surface of another diaphragm due to the motion of the first.

Wolff, I., and Malter, L. (1958) DIRECTIONAL RADIATION OF SOUND. J. Acoust. Soc. Am., 30, 201-241.

A discussion of the importance of the directional characteristics of loudspeakers from the standpoint of good reproduction of sound in small rooms and auditoriums. Calculated results will be given for a number of ideal sound radiators and experimental measurements will be given in a number of typical cases.

Zverev, V. A. (1956) THE POSSIBILITY OF AN ABSOLUTE CALIBRATION OF RADIATORS AND RECEIVERS OF SOUND WITH RESPECT TO RADIATION PRESSURE WITHOUT USING A RADIOMETER. Sov. Phys.-Acoust., 2 406-407.

Taking the expression for the sound pressure on an absorbing wall it is shown how, using a receiver of sound of a frequency ω, modulated at a frequency Ω, providing the receiver accepts both frequencies, to effect an absolute calibration.

Zverev, V. A. (1957) THE EFFECT OF THE DIRECTIVITY OF A RECEIVER DEVICE ON THE MEAN INTENSITY OF A SIGNAL RECEIVED AS THE RESULT OF SCATTERING. Sov. Phys.-Acoust., 3, 348-357.

The author examines the effect of the shape of the receiver polar diagram upon variation with scattering angle of the intensity of received radiation. It is shown that to solve the scattered intensity problem, it is sufficient to know that correlation function in the transverse direction for a distance not exceeding the dimensions of the receiver.

APPENDIX

List of Abbreviations

Acustica	Acustica
Akust. Beih.	Akustische Beihefte
Alta Frequenza	Alta Frequenza
Am. J. Phys.	American Journal of Physics
Ann. Telecomm.	Annales de Telecommunication
Arch. elekt. Ubertragung	Archiv der elektrischen Ubertragung
Bell System Tech. J.	Bell System Technical Journal
Can. J. Phys.	Canadian Journal of Physics
Compt. rend. (Paris)	Comptes rendus hebdomadaires des seances de l'academie des sciences
Compt. Rend. (USSR)	Comptes Rendus (Doklady) de l'Academie des Sciences, USSR
Dokl. Acad. Nauk, SSSR	Doklady Akademii Nauk, SSSR
Elektrotech. u. Maschinenb.	Electrotechnik und Maschinenbau
Fernmeldetech. Z.	Fernmeldetechnische Zeitschrift
Funk u. Ton	Funk und Ton
Geophysics	Geophysics
Hochfrequenztech. u. ElektAkust.	Hochfrequenztechnik und Elektroakustik
Izv. Akad. Nauk, SSSR, Ser. Fiz.	Izvestiya Akademii Nauk, SSSR, Seriya Fizicheskaya
J. Acoust. Soc. Am.	Journal of the Acoustical Society of America
J. Appl. Mech.	Journal of Applied Mechanics
J. Opt. Soc. Am.	Journal of the Optical Society of America
J. phys. radium	Journal de physique et le radium
J. Phys. Soc. Japan	Journal of the Physical Society of Japan
J. Phys. USSR	Journal of Physics, USSR
J. Soc. Motion Picture Engrs.	Journal of the Society of Motion Picture Engineers
J. Tech. Phys. USSR	Journal of Technical Physics, USSR
Nachrichtentechnik	Nachrichtentechnik
Nature	Nature

OSRD	Office of Scientific Research and Development
Phil. Trans.	Philosophical Transaction of the Royal Society of London
Philips Res. Rep.	Philips Research Reports
Phys. Rev.	Physical Review
Physica	Physica
Pont. Acad. Sci., Acta	Acta, Pontificia Academia Scientiarum
Proc. Cambridge Phil. Soc.	Proceedings of the Cambridge Philosophical Society
Proc. Phys. Soc. (London)	Proceedings of the Physical Society (London)
Rev. Sci. Instr.	Review of Scientific Instruments
Ricerca Sci.	Ricerca Scientifica
Sov. Phys.-Acoust.	Soviet Physics-Acoustics
Z. angew. Phys.	Zeitschrift fur angewandte Physik
Z. Physik	Zeitschrift fur Physik
Zh. Eksper. Teor. Fiz.	Zhurnal Eksperimentalkoi i Teoreticheskoi Fiziki

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A Bibliography on Acoustic Sources and Their Related Fields, G. B. Thurston and R. Stern

Report No. 2784-2-S, February, 1959, 65 pp., [Contract No. Nonr-1224 (24)] UNCLASSIFIED

This report is a bibliography on acoustic sources and their related fields. Both single sources and arrays of sources have been considered. The abstracts are arranged into a detailed subject outline having four major topics: Single Sources and Receivers; Arrays of Sources and Receivers; Transducer Properties; Acoustic Fields. Articles published during the period from 1935 to 1958 are reviewed principally.

Primary Field: Physics

Secondary Fields: Detection; Astronomy, Geophysics; and Geography

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