

The Recording and Reproduction of Sound



OLIVER READ, D.Sc., D.Litt.
Editor, Radio and Television News
and
Radio-Electronic Engineering



HOWARD W. SAMS & CO., INC.
INDIANAPOLIS 5, INDIANA
1952

PUBLISHER'S NOTE

The demand for, and the acceptance accorded, the first edition of this work has provided the stimulus for the present greatly expanded and revised volume. With more than twice the number of pages, this second edition includes many new and timely chapters, so that the work is in every sense a complete reference to all phases of audio. The text is written at a practical level, yet includes essential technical data in mathematical form to cover the subjects adequately. Prepublication of this new volume has been undertaken as a continued service toward the advancement of knowledge in the audio field both as it applies to commercial application and to use in the home. The text and opinions expressed are those of the author.

HOWARD W. SAMS & CO., Inc.

COPYRIGHT, 1952, BY
HOWARD W. SAMS & CO., INC.

Printed in the USA

All rights reserved. This book, or parts thereof, may not be reproduced in any form without written permission of the publisher.



ABOUT THE AUTHOR

The publication of the second edition of *The Recording and Reproduction of Sound* compiles in a single volume the detailed results of many years of exhaustive research and experimentation by the author, Dr. Oliver Read. The immediate acceptance of the first edition encouraged further writing on many new chapters as well as expansion of much of the earlier material. As Editor of *RADIO & TELEVISION NEWS* and *RADIO-ELECTRONIC ENGINEERING*, Dr. Read has long been a direct observer of the audio industry, both in the role of a hobbyist as well as professionally.

Author of many articles on recording and reproduction, notably "*The Theory and Practice of Disc Recording*," "*Building Your Own Recording Studios*" and "*A Flexible Record-Reproduce System*," Dr. Read possesses an enthusiasm and interest in the subject which he reflects in the practical treatment he accords Audio in all of its numerous phases. To keep abreast of the field, he maintains a fully equipped laboratory in his home for experimental work on tape, disc and wire recording and reproduction and for the study of home music systems. He witnessed the Atom Bomb tests at Bikini and recorded the events on wire.

Dr. Read is a member of the IRE Professional Group on Audio, The Society of Motion Picture and Television Engineers, Acoustical Society of America, Audio Engineering Society, Chicago Acoustical and Audio Group, British Sound Recording Association, American Institute of Physics and the Armed Forces Communications Association.

He maintains a broad and active interest in all developments in the audio, radio, television and electronic fields, each of which has made its own contribution to the advancement of the art of recording and reproducing Sound.

Preface

A complete reference to the many subjects in the general category of sound recording and reproduction has long been wanting. The need for ready reference on audio in all of its many phases has been repeatedly expressed by the audio engineer, the audiophile, sound technician, student, recordist, PA service technician and others engaged in the recording or reproduction of sound by means of disc, tape, wire or film.

Numerous articles have appeared in technical and non-technical journals covering various aspects of sound and their relation to recording techniques and methods of reproduction. Scattered as these articles are, it becomes a problem of continuous research and reference to hunt through such material, both foreign and domestic, to locate information on specific subjects in so wide a field.

Accordingly, **THE RECORDING AND REPRODUCTION OF SOUND** has been written to cover, in a single volume, all the essential requirements for a complete understanding of all currently employed systems and to include specific data on the components that determine the final result.

In the design of apparatus for the recording or reproduction of sound, the ultimate destination of the transmitted energy impulses is the human ear. The sequence of events (including acoustics) occurring from the time sound leaves its source until it arrives at the human ear, is a fascinating subject, rich with interesting phenomena. Acoustics has its inductance, capacitance, resistance; in fact, practically all the elements found in electrical circuits. It is our purpose to discuss acoustics insofar as it applies to the explanation or use of specific apparatus.

The recording and reproduction of sound is a complex subject embracing many methods and techniques. New developments are increasing practical applications for sound reinforcement, and magnetic recording units have proved their capabilities for use in the studio, in the home and in commerce. Microgroove records are contributing better music at lower cost to the masses. Magnetic pickups of the variable reluctance type have proved their worth and new reproducers offer true fidelity reproduction.

The text of this volume includes an abundance of information for those primarily interested in getting the finest possible reproduction from all forms of recorded media. Complete systems are included and a wide choice of amplifiers is presented so that the reader may make his own selection to suit his own particular requirements. The book emphasizes subjects known to be of greatest interest to those engaged in the recording or reproduction of sound. It has been written at semi-technical or non-technical level, wherever possible, and a practical viewpoint has been taken in presenting the material. Finally, the book contains essential history which serves as a background for a complete understanding of the many methods and techniques employed in recording and reproducing sound.

The author wishes to express his appreciation to the following for their help in supplying photographs and other material used in this book:

Aerovox Corporation	Fairchild
American Standards Association	Fidelitone, Incorporated
Armour Research Foundation	General Electric Company
Berlant Associates	Indiana Steel Products Co.
Brush Development Company	Magnecord
Columbia	Minnesota Electronics Corp.
Eicor, Inc.	Minnesota Mining & Mfg. Corp.
Electro-Voice	National Association of Broadcasters

Radio Corporation of America
Radio & Television News
Radio & Television News, Radio-Elec-
tronic Engineering Edition
The Radio-Television Manufacturers
Association
Society of Motion Picture and Television
Engineers

Shure Bros.
Standard Transformer Corporation
Sylvania Electric Products Co., Inc.
United Transformer Co.
Western Electric Company, Inc.
Westrex Corporation

And to Harold Renne, E. Hitzel and J. Juster for their help in the preparation of the manuscript.

Table of Contents

CHAPTER 1

Behavior of Sound Waves 1

Definition of Sound—Amplitude—Frequency—Complex Waves—Pitch—The Octave—Intensity—The Decibel—Periodicity—Waveform—Timbre—Distortion—The Ear—Quality—Fidelity—Speech—Music—The Scale—Frequency Range—Noise—Technical Aspects of Sound—Transverse Wave—Longitudinal Wave—Wavefront—Harmonic Motion—Periodic Motion—Random Motion—Period—Wavelength—Fundamental Frequency—Harmonic Frequency—Sub-Harmonic Frequency—Plane Wave—Transducer—Phase—Constructive Interference—Destructive Interference—Beats—Standing Wave—Spherical Wave—Fourier's Theorem—Anti-Nodal Points—Nodal Points—Speed of Sound—Pitch and Intensity—The Bel—Reference Level—Loudness.

CHAPTER 2

History of Acoustical Recording 10

Thomas Edison—The Ediphone—The Phonograph—The Dictaphone—Alexander Graham Bell—The Gramophone—Phonograph—Volta—Berliner—Eldridge Johnson—Diaphragm—Sound Boxes—Electro-Deposition—Speed Regulator—The Auxetophone—Parsons, Sir Charles—Bar—Valve (Air Pressure)—Damping—Victrola—Acoustical Reproducer—Master Record—Electrical Recording—Pickups—Capacity Pickup.

CHAPTER 3

Basic Recording Methods 18

Sound On Disc—Engraving—Cutting Head—Groove—Land—Chip (Scrap)—Embossing—Constant Groove Speed—The Gray Audograph—Flux (lines of)—Angular Velocity—Sound on Film (optical)—Movietone—Variable Density—Variable Area—RCA Photophone—Light Valve—Lens Systems—Variable Area Recording—Embossing Sound on Film—Filmgraph—Indenting—Recordgraph—Automatic Trackover—Western Electric "Hill and Dale" Recording—Magnetic Sound for Motion Pictures—35 mm. Recording Machine—Magnetic Film—Magnetic Heads (film)—Monitor (Sound on Film)—Sound Tracks (film)—Binaural and Stereophonic Film Recording—Film Recording System (magnetic)—Operation (film)—Magnetic Recording on Tape, Disc and Wire—Essential Components—Combined Heads—Supersonic Oscillator—Bias—Basic Wire Heads—Retentivity.

CHAPTER 4

Lateral Disc Recording 34

The Cutter Head—Amplitude Characteristics—Recording Characteristics—Constant Velocity—Stylus Velocity—Groove Displacement—Overcut—Constant Amplitude—Crossover—Corrective Network—Surface Noise—Rumble and Vibration—Orthocoustic Recording—NAB Standards—Playback Characteristic—Magnetic Cutters—Damping—Mounting—Motorboard Vibration—Cabinet Vibration—Mechanical Feedback—Test Record—Recording Styli and Cutting Pressure—Recording Level—Impedance Matching—Cutter Impedance—Total Impedance of Cutter and Auxiliary Circuits—Magnetic Cutters for Professional Applications—Temperature—Groove Dimensions—Stylus Adjustment—Noise Test—Determining Recording Level—The Crystal Cutter—Surface Noise—Noise Reduction—Characteristics of Crystal Elements—Piezoelectric—Bender—Twister—The Bimorph—Temperature Range—Operation of Crystal Cutter—Coupling Circuits—Turns Ratio—Mounting the Crystal Cutter.

CHAPTER 5

Disc Recorders 57

Introduction—Home Recording Technique—Home Recording Styli—Home Recording Blanks—as PA System—Description—Mixing—Monitoring—Stylus Angle Adjustment—Depth of Cut—Adjustment of Arm and Feed Screw—Reproducing Crystal and Needles—Recording Head—Microphones—Copies—Maintenance—Meissner 4DR (specs)—Professional Disc Recorders—RCA 73B—Diagram—Specifications—Disc Recording Filters—Cutter design—Crossover Filter Design—Operating Characteristics—Response Curves—Cutter Calibration—Presto Models 8D and 8D-G Recorders—Fairchild 539 Disc Recorders—Fairchild 523 Studio Recorder.

CHAPTER 6

Microgroove Recording 89

Columbia LP and RCA 45 microgroove—Styli—Pickups—Specifications and Playing Time—Fine Groove Modification—Kit—Recording Technique—Groove Dimensions—Tracing Distortion—Cutter Bounce—Force Gauge—Bounce Measurements—Dashpot—Recorder Action—Pivot—Lacquer Variation.

CHAPTER 7

Recording (Cutting) Styli 103

Types—Sapphire—Alloy—Steel—Cutting Angle—Hi Fidelity Recording—Recording—Recording Levels—Filters—Flutter—Cutter Adjustments—Tests—Groove Spacing—Burnishing Facet—Capps—Noise Modulation—Anti-noise Modulation—Stylus—Variations—Noise Factor—V-Groove Recording Styli—Columbia Hot Stylus Recording—Conventional Lacquer Styli—Measurement Technique—Frequency Response—Heated Stylus Performance.

CHAPTER 8

The Decibel 124

Determination of Ratios—Conversion Chart—Relationships—Applications—Use of Slide Rule—Reference Charts—Power Level—VI Meters—Rectifier Meters—The VU Meter—Characteristics—Scales—Power Level Meters—Attenuators—Bridging Loss.

CHAPTER 9

Phono Reproducers (Pickups) 138

Crystal Cartridges—Equalizers—Temperature and Humidity Effects—PN Cartridge—Lever Type—Magnetic Reproducers—FM Pickup—Strain-Sensitive Pickup—AM Pickup—Tuned Ribbon—GE Variable Reluctance—Pickering—Fairchild Dynamic—Phono Cartridges for Standard 78 and for Microgroove—Electro Voice—Multi-Speed Changers—Universal Tip Styli—Dual Styli Cartridge—Audax—Astatic—GE.

CHAPTER 10

Tone Arms and Reproducing Styli 163

Types—Groove Skating—Styli and Record Wear—Pinching Effect—Permanent Styli—Development—Tip Materials—Check Chart—Astatic 7-D—Duplex Arm—Audax—Pickering—Gray.

CHAPTER 11

Magnetic (Tape and Wire) Recording 178

Methods—Theory—Camras, Marvin—Materials—Recording Bias—Ultrasonic Biasing—Properties of Magnetic Wire—Distortion—Magnetic Head Design—Frequency Response—Materials—Wire vs. Tape—Testing of Magnetic Tapes—HF Bias—HF Currents in Erasure—Curve Graphs—Harmonic Distortion—Establishing Bias Valves—DC Bias—Erasure by Permanent Magnet—Frequency Dependence—Visible Tracks—Time Effects—Noiseraser—Signal Transfer—Performance Testing.

CHAPTER 12

Magnetic Tape Recorders 209

Mechanical Requirements—Electronic Circuits—Functional Requirements—Record-Reproduce Heads—Hi-Impedance Head—Bias and AF Current Requirements—Noise—Erasing—Circuits—Equalization—Frequency Response—Soundmirror—Tape Systems—Eicor Dual-Track—Drive Assembly—Motor—Capstan—Belt Idler Wheel—Inspection—Amplifier—Indicator—Hum Test—Operational Failures—Specs—Professional Tape Recorders—Design—NARTB Speeds—RCA-RT-11A—Presto RC-10/14/24—Presto 900-A2 and 901-A1 Amplifiers—Maintenance—Distortion—Stancil-Hoffman R4—Minitape Recorder—Miniaturized Playback Amplifier—Multi-Channel Recorder—Magne-corder PT 63-A—PT 63-J Amplifier—PT 7-AX and PT 7-C Magnecorders—Studio Console.

CHAPTER 13

Magnetic Film Recorders 266

Westrex RA-1467 Professional Magnetic Recording System for 35, 17½ and 16 mm. Films—Description—ASA—Recorder—Film Path—Controls—Structure—Drive—Transmission System—Amplifier—Bias Oscillator—Power Supply—Mixer—Equalizers—Control Unit—Performance—Stancil-Hoffman S4—Description—S3 Amplifiers—Rangertone R-5PM Synchronous Tape Recorder—Monitoring—Motion Picture Application—Dubbing—Post Synchronizing—Playback—Flutter.

CHAPTER 14

Microphones 284

Types—Carbon—Crystal—Sound Cell—Differential—Non-Directional—Dynamic—Broadcast—Moving Coil—Western Electric 618-A—Eight Ball, 630-A—Velocity, RCA 44-BX—Unidirectional Velocity, RCA 77-A—Polydirectional, RCA 77-D—Cardioid, WE 639-A—Cardioid Crystal, Astatic DR-10—Condenser, WE 640 AA—Controlled Reluctance, Shure Bros.—Miniature Microphones—Altec 21B—Stevens C-2S—Electro Voice 636—EV 655 Dynamic.

CHAPTER 15

Loudspeakers and Enclosures 315

Design Requirements—Speaker Placement—Resonance—Damping—Response—Corner Enclosure—Electrical Damping—Feedback and Phase Shift—Enclosures—Flat Baffle—Vented Cabinets—Bass Reflex—Klipschorn Corner Cabinet—Auditory Perspective—Theatre Systems—Multiple Speakers—Labyrinth Enclosure—Closed Box Baffles—Cones—Accordion Cone—Coaxial Reproducers—Triaxial Speaker—Jensen G-610—Distribution Angle—Loudspeaker Behavior—Cabinet Design Data for 15" Mechanisms—Measurements—Cabinet Volume—Wall Construction—Damping—Mounting—Configuration—Electro Voice SP12-B—Jim Lansing—Racon Tweeter—Atlas Tweeter—Conclusion.

CHAPTER 16

Dividing Networks and Filters 354

Introduction—Dividing Networks—Position of Network—Use of Tables—Design of Audio Networks—Attenuating Equalizers—Types—Filter Networks—Frequency Dividing Networks—Impedance Matching.

CHAPTER 17

Tone Control (Equalizers) 385

Resistance-Capacitance (R-C) Networks—Tone Compensation Systems—Position in Amplifier—Calculations—Resonant Equalizers—Commercial Equalizers—Degenerative Tone Control—Noise Suppression Filters—Record Equalizers—Record Compensators—Program Equalizers.

CHAPTER 18

Attenuators and Mixers 406

Input Coupling Methods—Attenuators for Recording and Broadcast—Public Address Attenuators—Fixed Attenuators and Pads—Classifications—T Pad—Potentiometers—Mixer Circuits—Ladder Mixers—Linear Control—Master Controls—Mixers for Recording and Broadcast—Constant Impedance Mixing—Parallel Mixers—Series Mixers—Splitting Pads—Power Loss of Pad—Delta to Star Conversion—Practical Application—Matching with Series Resistors.

CHAPTER 19

Amplification 420

Classification—Voltage and Power Amplifiers—Coupling Methods—Phase Inverters—Circuitry—Cross-Coupled Input and Phase Inverter—Circuit—Application in Instruments—Audio Applications—Expansion—Conclusions—Pre-Amplification—Hum Isolation—Microphonics—Program or Line Amplifiers—Remote Amplifiers—Circuit Analysis—Two-tube Phono Amplifier—10 watt ac-dc Amplifier—8 watt Amplifier with Cathode Follower—10-16 watt Amplifier—8 tube Amp. with Volume Expander—Tone Control—Recording Amplifiers—Triodes—Monitor Channel—A 10 watt Amplifier with Expansion—Dynamic Noise Suppression—Analysis—Location—Effects—Low Distortion Volume Expansion.

CHAPTER 20

Preamp-Equalizers 472

A Preamp for Magnetic and Crystal Pickups—Equalizer Design—An Improved Equalizer—Preamp—Design Charts—Commercial Preamp-Equalizers—McIntosh AE-2A—Scott Dynaural Preamp—Turnover Control—Constant-Amplitude Pickup Compensation—Goodell PRA-1 Preamplifier Driver.

CHAPTER 21

Music Systems 496

Audio Quality—High Frequency Response—Bass Response—Definition—Naturalness—Presence—Dynamic Range—Amplifiers for Home Music Systems—McIntosh Amplifier—Electrical Design—The Williamson Amplifier—Performance—Electronic Workshop A-20-5 System—Package Systems—Physical Requirements.

CHAPTER 22

PA Sound Systems 519

Applications—General System Plan—School System—Markets—Gain—Noise—VI Setting—Output Load Impedance—Western Electric Systems—Power Distribution—Auditorium Loudspeaker Volume—Efficiency of Classroom Loudspeakers—Outdoor Announcing System—Hotel System—Guest Room Loudspeakers—Auditorium System—Indoor Speech System—PA Mobile Unit—Power Plant—Distribution of Load—Generator Noise—Emergency Source—Loudspeakers—Power Requirements—Amplifiers—Tuner—Recorders—Turntables—Microphones—Field Telephones—Church Tower Systems—Location—Requirements—100 watt System—Phasing—Power Overload and Protection—Series vs. Parallel Operation—Precautions—Overload Protection—Radial Reflex Projector—Exponential Re-Entrant Trumpets—Straight Exponential Horns—Railway Speakers—Horizontally-concentrated Horns—Driver Units—Multicellular Horns and LF Speakers—PA Maintenance—Measurements.

CHAPTER 23

Acoustics 552

Auditorium Acoustics—Structural Noise—Insulating Walls—Inside Noise—Reducing Reverberation—Acoustical Materials—Size Limits—Dead Areas—Fidelity—Measurements—Acoustic Properties—Acoustic Measurements—Acoustic Characteristics—Sound Level and Power Measurements—Results in Practice—Audio Power Requirements—Loudspeaker Efficiency.

CHAPTER 24

Tuners (AM-FM) 569

Wide Range Bandpass Crystal Tuner—The TRF Tuner—Alignment—Miniature Superhet AM Tuner—Operadio AM-FM Tuner—Espey AM-FM Tuner Chassis—Collins FM-AM Tuner—Craftsmen RC-10 Tuner—Equalizer.

CHAPTER 25

Speech Input Systems 580

Introduction—Program Production and Dispatching—Symbol Key Sheet—Program Production Unit—Program Blending—Level Controls—Indicators—Main Amplifier—Monitoring Facilities—Impedance Stabilization—Master Dispatching Equipment—Program Sampling—Program Distribution—System Applications—Components for Speech Input Systems—Speech Input Console—Specifications—The Remote Amplifier—The Cueing Amplifier—The VU Panel—Attenuator Panels—The Booster Amplifier—The Program Amplifier—The Monitor Amplifier—The Limiting Amplifier.

CHAPTER 26

Complete Recording Systems 604

Semi-Professional Recording System—The Preamp—Equalizer—The Line Amplifier and Bridging Bus—The Jack Field—The Main (Recording) Amplifier—The Monitor Amplifier—Spare Amp—FM-AM Tuner—Television Tuner—Speaker Lines—Recording Turntables—Tape Recorder—Meter Panel—Circuitry—Patch Cords and Plugs—Bridging Bus—Commercial Recording Systems—Studio Requirements—NARTB Equalization—Multichannel Mixing—Diameter Equalization—Equalizing Pickups—Patching Circuits—Dubbing—Portable Recording Console—Function.

CHAPTER 27

Record Manufacture (Pressings) 634

Processing—Manufacturing Techniques—Sensitizing—Electro Deposition—Copper Plating—Metal Master—Mother—Stamper—Production Control—Pressings.

CHAPTER 28

Audio Measurements 641

Distortion—Amplitude—Frequency—Phase Shift—Harmonic Analyses—Wave Analysis—Sine Wave—Intermodulation—Non-Linearity—Intermodulation Analyzer—Intermodulation Distortion Meter—Signal Generator—Frequency Response Measurements—Sweep Frequency Techniques—Phase Shift Technique—Phase Distortion—Frequency Bridges—Square Wave Testing—Clipping—Routine Amplifier Tests—Gain—Feedback—Impedance—Power Output—Hum and Noise Level—Control of Hum—Hum Characteristics—Cutter Head Response Measurement—Light Patterns—Frequency Records—Microscope Method—Photocell Method—FM Method—Monitoring—Measurement of Sound—Sound Levels.

CHAPTER 29

Recording and Reproducing Standards 684

NARTB Standards for—Mechanical—Magnetic—Optical—Recording—Reproducing—Glossary of Terms and Definitions.

Appendix 709

Disc recording adjustments—Glossary—Bibliography of magnetic recording—Condenser color code—Transformer color code—Resistance color code—Formulae—Mathematical symbols and constants—Fundamental electrical law—Properties of vacuum tubes—Amplifier classification—Radio terms—Resistance coupled amplifier data—Tables—Decibel table—Logarithm tables—T and H pads—Filter design—Feedback.