ACOUSTICAL MEASUREMENTS

REVISED EDITION

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Preface to the Revised Edition

Forty years have passed since the manuscript for the first edition of *Acoustic Measurements* was completed. That era coincided with a vigorous expansion of theory, experiment, education, applications, and government support of acoustics throughout the world. The annual number of pages published in the Journal of the Acoustical Society of America has increased five-fold since 1948. Ten technical periodicals in the field, compared to one, are found in our libraries. Important acoustical research laboratories have been established in nearly every industrial country.

In the first edition, little space was devoted to the sound level meter, today's most basic sound measuring instrument. The sound level meter of the 1940s was usually equipped with a Rochelle salt crystal microphone, which was grossly sensitive to temperature and dissolved in high humidity and high temperature. Calibration of a sound level meter, even years after purchase, was seldom made and the user needed a strong back or a rolling table while taking data.

Analyzers were primarily laboratory research instruments and no high-fidelity apparatus for recording sound, except the optical track on movie film, was commercially available.

Nevertheless, one acoustical measurement device has, like the Rock of Gibraltar, stood unchanged since those days, namely, the National Bureau of Standards Type 9A coupler for measuring audiometric earphones. Other measuring equipment that have prevailed are condenser microphones, apparatus for reciprocity calibration of them, and graphic level recorders of the moving-coil-actuated type.

Today's sound and vibration level meters, analyzers, recorders, and computers are a triumph of solid-state electronics which permit a variety of accurate measurement functions. Microphones, vibration pickups and their associated amplifiers are highly stable and suited to widely varying ambient conditions. Sound, noise, and vibration generators assist every class of field

and laboratory measurement. Recently, the intensity meter, which measures acoustic energy flow in any direction in complex noise fields, has come into use.

This revised edition of the original *Acoustic Measurements* attempts to cover many of these developments. Primarily owing to the lack of space, it does not deal with the design of digital equipment or with digital computer programs. References to these are given in the Appendix. The engineer must understand the basic physical laws of analog filters and signal processors to use digital equipment intelligently because both obey the same rules.

Over one-half of the pages in this edition are new, and twelve of the twenty chapters have been rewritten or revised in major ways. No attempt has been made to update the "History" section, mainly because of lack of time. Some of the more interesting earlier methods of sound measurement have been retained to illustrate the range of possibilities.

I wish to thank colleagues and equipment manufacturers who helped me with concepts and furnished me with drawings. My appreciation extends to Mary M. Smith in the Art Department of Bolt Beranek and Newman, Inc., for preparing many of the illustrations. It is my hope that the revised and renamed *Acoustical Measurements* will justify the confidence that the Acoustical Society of America has shown in producing a new edition.

Leo L. Beranek

Cambridge, Massachusetts
July 1988

Preface to the Original Edition

This book is intended primarily as a reference for graduate students and workers in the field of acoustics. I have attempted to cover the subject of acoustic measurements in such a way that the book will be an aid to five main groups of research workers: the acoustic physicist making fundamental laboratory measurements, the communications engineer measuring and evaluating the performance of audio communication systems, the psychologist performing measurements involving the human hearing mechanism, the otologist studying hearing defects, and, finally, the industrialist applying acoustic measuring techniques in manufacturing processes.

Acoustic measurements are sufficiently complex to require a knowledge of the fundamental factors involved in any given measurement and of the various apparatuses that will perform the measurement. This book gives the mathematical equations underlying each type of acoustic measurement; it describes and compares the relative advantages and disadvantages of alternative apparatuses. The resultant text is somewhat longer than that originally contemplated, but it is hoped that the increase in reading matter will effect a net saving in time for the experimenter.

I wish to express my indebtedness to many of my colleagues and fellow workers in the field of acoustics whose aid has been invaluable both in obtaining material and in reading and criticizing the manuscript. I am especially grateful to Dr. R. H. Nichols, Jr., of the Bell Telephone Laboratories, who, in addition to preparing the text for Chapters 8 and 14, devoted much time to editing and correcting the manuscript. Dr. James P. Egan of the University of Wisconsin gave kind permission to use material from one of his reports in Chapter 17.

I also wish to thank Clare Twardzik, who prepared the illustrations; Elizabeth H. Jones, who typed the manuscript; and Mr. Wilmer Bartholomew, who gave valuable assistance in editing the final manuscript.

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Finally, I am grateful to my wife, Phyllis Knight Beranek, who assisted in the reading of the galley and page proof and who helped in many other ways.

I am aware that, in spite of every effort to the contrary, there will be errors in the following pages. I assume responsibility for them, and I trust that my readers will be kind enough to point them out.

L. L. B.

Cambridge, Massachusetts
March, 1949

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