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RADIATION LABORATORY SERIES

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TECHNIQUE OF MICROWAVE MEASUREMENTS

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TECHNIQUE OF MICROWAVE MEASUREMENTS

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Foreword

THE tremendous research and development effort that went into the development of radar and related techniques during World War II resulted not only in hundreds of radar sets for military (and some for possible peacetime) use but also in a great body of information and new techniques in the electronics and high-frequency fields. Because this basic material may be of great value to science and engineering, it seemed most important to publish it as soon as security permitted.

The Radiation Laboratory of MIT, which operated under the supervision of the National Defense Research Committee, undertook the great task of preparing these volumes. The work described herein, however, is the collective result of work done at many laboratories, Army, Navy, university, and industrial, both in this country and in England, Canada, and other Dominions.

The Radiation Laboratory, once its proposals were approved and finances provided by the Office of Scientific Research and Development, chose Louis N. Ridenour as Editor-in-Chief to lead and direct the entire project. An editorial staff was then selected of those best qualified for this type of task. Finally the authors for the various volumes or chapters or sections were chosen from among those experts who were intimately familiar with the various fields, and who were able and willing to write the summaries of them. This entire staff agreed to remain at work at MIT for six months or more after the work of the Radiation Laboratory was complete. These volumes stand as a monument to this group.

These volumes serve as a memorial to the unnamed hundreds and thousands of other scientists, engineers, and others who actually carried on the research, development, and engineering work the results of which are herein described. There were so many involved in this work and they worked so closely together even though often in widely separated laboratories that it is impossible to name or even to know those who contributed to a particular idea or development. Only certain ones who wrote reports or articles have even been mentioned. But to all those who contributed in any way to this great cooperative development enterprise, both in this country and in England, these volumes are dedicated.

L. A. DuBRIDGE.

Preface

THE development and engineering of microwave radar equipment required that considerable effort be spent on improvements in the art of microwave measurements. New techniques had to be devised which were suitable for laboratory use, and these had to be modified and adapted for use in the field and in the factory. The necessity for the maintainance and the repair of military equipment imposed other special problems, and test gear had to be designed for these purposes also. A large portion of this test equipment was highly specialized and suited only for a particular purpose. No standard methods that were commonly acknowledged were available. Moreover, the precision and the convenience of operation of various pieces of measuring equipment varied widely. It has been attempted in the present volume to select for description those techniques and apparatus which are most likely to prove useful to future workers in the microwave field rather than to attempt a compilation that approaches completeness. Emphasis has been placed on laboratory equipment, since it is difficult to predict what future applications will be important.

Most of the methods to be described are based on the wave character of high-frequency currents, rather than on the low-frequency techniques of direct determination of current or voltage. The techniques to be described are grouped under four main headings:

I. Power Generation and Measurement.
II. Wavelength and Frequency Measurements.
III. The Measurement of Impedance and Standing Waves.
IV. Attenuation and Radiation Measurements.

Parts I and II need no further comment except that the measurements peculiar to radiation from pulsed generators are included as Chap. 7 of Part II. The numerous bridge measurements, so important in the low-frequency region, cannot be easily modified for microwave work, but analogous methods have been devised and show great promise for future development. These methods are discussed in Chap. 9 of Part III. The inclusion of the measurements of dielectric constant in Part III is based on the fact that it is the dielectric constant which determines the intrinsic impedance of a medium, since the permeability of nearly all

substances is very closely the same as that of a vacuum. Although attenuation and radiation measurements are essentially measurements of power, the special devices employed make it convenient to consider such measurements in a separate part.

It is a pleasure to acknowledge the cooperation of the many individuals who contributed to the preparation of this volume. In addition to those specifically named on a preceeding page in the list of authors and editorial staff, acknowledgement is due to Miss Ruth Kaufman for editorial assistance, to Mrs. Ruth Shoemaker who collated most of the photographs, and to Dr. V. Josephson for his able direction of the drafting staff.

CAROL G. MONTGOMERY.

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