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KLYSTRONS AND MICROWAVE TRIODES

By

DONALD R. HAMILTON

ASSISTANT PROFESSOR OF PHYSICS, PRINCETON UNIVERSITY

JULIAN K. KNIPP

ASSOCIATE PROFESSOR OF PHYSICS, IOWA STATE COLLEGE

J. B. HORNER KUPER

BROOKHAVEN NATIONAL LABORATORY

EDITORAL STAFF

GEORGE B. COLLINS · ALBERT G. HILL · WINIFRED MCCULLOCH

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KLYSTRONS AND MICROWAVE TRIODES

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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

THIS volume of the Radiation Laboratory Series attempts to cover the basic principles underlying the operation of klystrons and planar grid tubes as oscillators and amplifiers. It has been the desire of the authors to present the technical and theoretical aspects of this field as completely and as rigorously as possible, even though this meant the exclusion of a great deal of descriptive material, and has certainly added to the difficulty of a first reading. Nevertheless it was felt that the greatest need for a book on this subject at the present time was for one from which the fundamental principles for the design and understanding of microwave vacuum tubes could be obtained. No attempt has been made to describe how a vacuum tube is actually constructed. Rather the emphasis has been placed on presenting the fundamental material which the tube designer or tube user must have at his command.

Because the radio-frequency work of the Radiation Laboratory was concentrated almost entirely in the frequency region above 3000 Mc/sec, this book naturally tends to emphasize the operation of tubes in that region. However the basic principles are the same at lower frequencies although as a general rule the electrical and mechanical requirements become more difficult to attain as higher frequencies are approached. Certainly it is the authors' hope that this is a book on the principles of operation of particular types of tubes, and not a treatise on the generation of oscillations in a particular frequency band.

The wartime development of microwave radar and communications was based on three important types of amplifier and oscillator tubes: the multicavity magnetrons, the klystron family of tubes, and the planar grid tubes (also called lighthouse tubes and disk-seal tubes). The extraordinarily rapid engineering development of the multicavity magnetron as a transmitting tube is certainly one of the great advances of the war and is discussed elsewhere in the Radiation Laboratory Series. The present volume attempts to complete the story, and to cover in particular the development of microwave receiving tubes, local oscillators, and signal amplifiers. The use of klystron and planar grid tubes as transmitting oscillators, and in a few cases transmitting amplifiers, is not neglected. But up to the present their greatest use has been in receivers. It seems hardly necessary to caution the reader that the future develop-

ment of microwave receiver tubes will hardly be limited to the two types discussed here. One need only recall the announcement in June of this year of the development first at Oxford University and later at the Bell Telephone Laboratories of the traveling-wave tube, which may well revolutionize our idea of amplifier design.

This volume has been written in parts based on tube types and construction, a division in form rather than in use or purpose. Following four introductory chapters discussing tube types and functions and basic electronic and circuit phenomena common to all types of tubes there is a part on planar grid tubes and a part on klystrons. This division has seemed desirable to the authors since it has made the purely mathematical developments more logical than would have been the case if the division in function had been followed. This arrangement should reduce the number of cross references, and make the reading more straightforward. Aside from a few special cases of r-f circuits which are used solely for microwave vacuum tubes, no attempt has been made in this book to discuss the general properties of distributed constant circuits, since these problems have been discussed thoroughly elsewhere in this series.

Except for the important work of H. V. Neher and his group, most of the effort at Radiation Laboratory on microwave receivers went into the design of circuits, and the corollary tube testing and specification. We have drawn freely upon the work of other organizations both in England and in this country, and in particular upon the work of the Bell Telephone Laboratories, the General Electric Company, and the Sperry Gyroscope Company. Since the bulk of the wartime work has just been declassified and remains unpublished, it has been necessary to refer to internal organization reports, which are not available generally.

With the increasing awareness of engineers and physicists of the relative merits of various systems of units, it has become the duty of the preface writer to mention and defend the system chosen for the book at hand. The present volume uses the MKS system for reasons no more cogent than (1) this system is becoming more and more popular among engineers, and is making headway even among physicists; (2) amperes, ohms, and volts are units which the tube designer naturally uses.

We should like to express our thanks to Professor Eugene Feenberg, now at Washington University in St. Louis, Mr. Edward Barlow, and Dr. Marvin Chodorow, of the Sperry Gyroscope Company for many helpful comments and criticism of the manuscript. We are indebted to our former colleagues Dr. Milton Gardner, now at the University of California, and Mr. M. C. Waltz, now at the Bell Telephone Laboratories, for a great deal of help in preparing the information for

this volume. In particular we wish to thank Dr. W. G. Shepherd, of the Bell Telephone Laboratories, who has read the entire manuscript and has helped us greatly by his criticism.

ALBERT G. HILL.

CAMBRIDGE MASS.,
July, 1946.

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