RADAR AIDS TO NAVIGATION

Edited by

JOHN S. HALL, PH.D.

ASSOCIATE PROFESSOR OF ASTRONOMY AND PHYSICS
AMHERST COLLEGE

OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT
NATIONAL DEFENSE RESEARCH COMMITTEE

FIRST EDITION

NEW YORK AND LONDON
McGRAW-HILL BOOK COMPANY, INC.
1947

RADAR AIDS TO NAVIGATION

THE MAPLE PRESS COMPANY, YORK, PA.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

RADIATION LABORATORY SERIES

---

1. RADAR SYSTEM ENGINEERING—*Ridenour*
2. RADAR AIDS TO NAVIGATION—*Hall*
3. RADAR BEACONS—*Roberts*
4. LORAN—*Pierce, McKenzie, and Woodward*
5. PULSE GENERATORS—*Glasoe and Lebacqz*
6. MICROWAVE MAGNETRONS—*Collins*
7. KLYSTRONS AND MICROWAVE TRIODES—*Hamilton, Knipp, and Kuper*
8. PRINCIPLES OF MICROWAVE CIRCUITS—*Montgomery, Dicke, and Purcell*
9. MICROWAVE TRANSMISSION CIRCUITS—*Ragan*
10. WAVEGUIDE HANDBOOK—*Marcuvitz*
11. TECHNIQUE OF MICROWAVE MEASUREMENTS—*Montgomery*
12. MICROWAVE ANTENNA THEORY AND DESIGN—*Silver*
13. PROPAGATION OF SHORT RADIO WAVES—*Kerr*
14. MICROWAVE DUPLEXERS—*Smullin and Montgomery*
15. CRYSTAL RECTIFIERS—*Torrey and Whitmer*
16. MICROWAVE MIXERS—*Pound*
17. COMPONENTS HANDBOOK—*Blackburn*
18. VACUUM TUBE AMPLIFIERS—*Valley and Wallman*
19. WAVEFORMS—*Chance, Hughes, MacNichol, Sayre, and Williams*
20. ELECTRONIC TIME MEASUREMENTS—*Chance, Hulsizer, MacNichol, and Williams*
21. ELECTRONIC INSTRUMENTS—*Greenwood, Holdam, and MacRae*
22. CATHODE RAY TUBE DISPLAYS—*Soller, Starr, and Valley*
23. MICROWAVE RECEIVERS—*Van Voorhis*
24. THRESHOLD SIGNALS—*Lawson and Uhlenbeck*
25. THEORY OF SERVOMECHANISMS—*James, Nichols, and Phillips*
26. RADAR SCANNERS AND RADOMES—*Cady, Karelitz, and Turner*
27. COMPUTING MECHANISMS AND LINKAGES—*Svoboda*
28. INDEX—*Henney*

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

RADAR AIDS TO NAVIGATION

EDITORIAL STAFF

L. A. TURNER, TECH. ED.

J. S. HALL, ED.

R. M. WHITMER, ASS'T. ED.

CONTRIBUTING AUTHORS

H. B. ABAJIAN
F. R. BANKS, JR.
J. H. BUCK
W. M. CADY
M. A. CHAFFEE
G. C. COMSTOCK
D. DAVIDSON
R. M. EMBERSON
A. G. EMSLIE
H. FAHNESTOCK, JR.
G. A. GARRETT
D. L. HAGLER
J. S. HALL
D. HALLIDAY
J. J. HIBBERT
N. W. MACLEAN
D. B. MCLAUGHLIN
R. E. MEAGHER
E. E. MILLER
R. H. MÜLLER
J. P. NASH
C. F. J. OVERHAGE
J. A. PIERCE
J. B. PLATT
R. M. ROBERTSON
E. L. SINSHEIMER
C. A. SMITH
H. P. STABLER
J. M. STURTEVANT
W. J. TULL
L. A. TURNER
T. H. WATERMAN
R. M. WHITMER

Preface

Radar Aids to Navigation is intended primarily to describe the advantages and limitations of radar equipment when applied to problems of navigation and pilotage, whether the equipment is airborne, shipborne, or ground-based. Radar beacons as aids to navigation are also discussed.

While the development of radar was proceeding apace under the impetus of the Second World War, the development of a host of nonradar navigational aids was also accelerated. These aids include systems that measure range differences like Loran and Gee and a number of azimuthal systems like the German Sonne. Descriptions of these and other nonradar aids are included to give the reader a more comprehensive picture of available techniques.

The authors have not always found it possible to present this information in a nontechnical form. The reader with no technical background should obtain a fair estimate of the value of radar in navigational problems from Chaps. 2, 3, 8, and 9. Radar indicators are described in some detail in this volume because, of all the components, they are of greatest interest to the navigator. A more detailed discussion of many of the engineering problems mentioned here is given in *Radar System Engineering*, Vol. 1 of this series.

In this volume, the emphasis is placed more on what can now be done with radar than on what should be possible in the future. A possible exception to this policy is the inclusion of several photographs of airborne radar indicators attached to radars with antenna beams 0.8° wide. Although these pictures illustrate what can now be done, beamwidths of 3° to 5°, rather than 0.8°, appear practical for airborne radars to be used as navigational aids in the near future. More emphasis has been placed on airborne radar used with beacons as an anticollision device on overwater flights simply because it does not appear reasonable to require that all airplanes flying over land have beacons.

A real effort has been made to define terms either explicitly or by their use. A certain amount of repetition results from this policy. For most radar applications described here, narrow antenna beams necessitating short wavelengths, or *microwaves*, are commonly prescribed. By

this term is meant radio waves between 1 and 12 cm long. It is not our intention to insult the reader's intelligence by defining words found in a small dictionary, nor even the word radar. There is no glossary. The definitions of many words may be found by reference to the index.

Thirty-three authors and many persons serving in other capacities have contributed to this book. Unfortunately it is not practical to give full acknowledgement to everyone. R. A. Whitmer, assistant editor, did a large share of the editorial work connected with the portion of the book devoted to airborne radar. L. A. Turner, technical editor, was a most constructive influence in clarifying many sections. His criticisms and suggestions were invariably followed. R. G. Herb served as technical editor during the formative stage of this project.

David Davidson deserves a solid vote of thanks for selecting the illustrations used in the sections on Loran and other navigational nets and for writing their captions. We are grateful also to M. G. White, D. T. Griggs, and R. J. Dippy for their criticism. We regretted to learn that illness prevented Dippy, the originator of Gee, from sending us a description of the miniature system similar to Gee that the British have recently used successfully as an airport approach system. Thanks are due to L. J. Laslett, R. M. Emberson, G. C. Comstock, M. A. Chaffee, and J. H. Buck for assistance in making the original outlines of the book. We are grateful to Beka Doherty who, as an uninhibited reader, read the final manuscript and made many helpful criticisms and suggestions.

We acknowledge with thanks the careful manner in which Louise Butler, our production assistant, guided the diagrams and photographs to their ultimate completion. A large amount of secretarial work connected with the book was cheerfully done by Bernyce Goldberg. Thanks are due to Eleanor Uhl who acted as editorial assistant during the formative stages of the book and particularly to Barbara Rudolph who bravely shouldered this responsibility during its critical final stages.

JOHN S. HALL.

CAMBRIDGE, MASS.,
June, 1946.

Contents

PART IV. SHIPBORNE RADAR