RADAR HANDBOOK

Editor in Chief

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PREFACE

This edition has been thoroughly revised to reflect the advances made in radar over the past two decades. There are many new topics not found in the original, and over half of the 25 chapters were written by authors who did not participate in the first edition. The continued growth in radar capability and applications is reflected in much of the new material included in this second edition. The following are some of the many new radar advances that have occurred since the original edition (listed in no particular order):

- The use of digital techniques that allow sophisticated signal processing in MTI and pulse doppler radars, as well as digital data processing to perform automatic detection and tracking.
- The use of the doppler filter bank and the clutter map in MTI radar.
- The reduced dependency on operators for extracting information from a radar and the incorporation of CFAR in automatic detection and tracking systems.
- The emergence of the analog SAW dispersive delay line as the preferred technique for wideband (high-resolution) pulse compression; the use of digital processing for the pulse compression filter when the bandwidth permits; and the introduction of Stretch pulse compression, which allows high resolution, over a limited range interval with considerably reduced processing bandwidth.
- The increased use of 3D radar for military applications.
- The introduction of the ultralow-sidelobe antenna for airborne pulse doppler radar and, later, for ECCM.
- The replacement of the parabolic reflector antenna with the planar-aperture array antenna for 3D radar, ultralow-sidelobe antennas, and airborne radar.
- The high-power solid-state transmitter that consists of many transistor modules distributed on the rows of a 3D radar (such as the AN/TPS-59), or employed at the elements of a phased array (as in PAVE PAWS), or configured as a transmitter for a conventional radar (as in the AN/SPS-40 or the Canadian ATC radar known as RAMP).
- The serial production of phased arrays for the Patriot, Aegis, PAVE PAWS, and B1-B radar systems.

- The interest in the radar cross section of targets brought about by the attempts to reduce the cross section of military vehicles; and advances in computer methods for predicting the cross section of complex targets.
- The increased capability of military airborne radar (airborne intercept, AWACS, and AEW) due to advances in components and technology that permitted the application of AMTI and pulse doppler to the detection of aircraft in the midst of large clutter.
- The use of radar in space for rendezvous and landing, remote sensing of the earth's environment, planetary exploration, and the detection of targets on the oceans of the world.
- The use of semiactive radar for the guidance of military missile systems.
- The extraction of the doppler frequency shift in meteorological radars that permits the recognition of hazardous weather phenomena not possible with previous weather radars.
- The use of radar operating in the HF portion of the spectrum for long-range over-the-horizon detection of aircraft, ships, and missiles, as well as to provide the direction of the surface winds and the sea state over wide areas of the ocean.
- The development of electronic counter-countermeasures (ECCM) in military radars to thwart attempts to negate radar capability by hostile electronic radiations.
- The increased range resolution and doppler resolution in synthetic aperture radars (SAR) for the imaging of a scene, the use of inverse SAR (ISAR) for the imaging of targets, and the replacement of optical processing with digital processing for SAR imaging.
- The adaptive antenna for application in sidelobe cancelers (as an ECCM) and AMTI radar.
- The use of computers to reliably and quickly predict the capability and coverage of radar systems in the real environment.

The purpose of the above listing is to indicate that radar is dynamic. Not all the new advances made since the first edition of this handbook are listed, nor does the list include all the new material discussed in this edition. There continue to be significant advances in the application of new technology and in the appearance of new applications. Radar grows and is viable since it satisfies important societal, economic, and military needs. It has no serious competitor for most of its many applications.

The size of this edition of the handbook is smaller than the original edition. This is more an indication of the problems involved in technical book publishing rather than problems with the health of radar or the

availability of material to include. It was not an easy task to constrain the chapter authors to a limited page budget, and I am appreciative of their efforts to keep the size of their chapters within the allocated number of pages. It would have been easy to double the size of this edition even without increasing the number of chapters. The limitation on size was one of the reasons a number of chapters found in the first edition do not appear here. Some of the omitted chapters were concerned with subjects for which there is not as much interest as there had been or whose technology has not advanced as much as other areas of radar. It is with some regret that 16 of the chapters in the original could not be included in this second edition.

As in the first edition, no attempt was made to utilize a standard notation throughout the book. Each particular subspecialty of radar seems to have developed its own nomenclature, and it is not appropriate in a book such as this to force authors to use notation that is foreign to their field even though it might be commonplace in some other aspect of radar.

Each chapter author was instructed to assume that the average reader has a general knowledge of radar but is not necessarily an expert in the particular subject covered by the chapter.

After a general introduction to radar in Chap. 1, there is a review of the methodology for predicting the range of a radar that has evolved over the years. This is followed by several chapters on the major subsystems of a radar: the receiver, transmitter, solid-state transmitters, reflector antennas, phased array antennas, data processing, ECCM, and pulse compression. Next are discussions of the target cross section and the nature of the radar echoes from the ground and the sea. The various types of radar systems are then discussed: CW and FM-CW, MTI, AMTI, pulse doppler, tracking, missile guidance, height finding and 3D, and synthetic aperture radar. This is followed by three specialized examples of radar that have their own unique character: radar in space, meteorological (weather) radar, and HF over-the horizon radar. The book closes with a treatment of the bistatic radar, which was the first type of radar explored during the onset of radar development in the 1930s.

I would hope that readers who refer in their own writings to material from this book do so by chapter author and title and not by citing just the "Radar Handbook." This will give proper credit to the individual authors who created the work.

It is with much pleasure that I acknowledge the contributions of the individual chapter authors. I enjoyed working with these talented radar engineers and having the opportunity to learn so much from my association with them. A handbook such as this exists only because of the dedicated efforts of the many experts who took the time and energy to

prepare the individual chapters. I appreciate their hard work in committing to writing their knowledge and experience, and I am grateful that they have shared this with us.

Merrill Skolnik

ABOUT THE EDITOR IN CHIEF

Merrill I. Skolnik, known worldwide for his leadership in radar research and development, has been affiliated with the Johns Hopkins Radiation Laboratory, Sylvania, MIT Lincoln Laboratory, the Research Division of Electronic Communications Inc., the Institute for Defense Analyses, and the U.S. Naval Research Laboratory. He received his doctorate in electrical engineering from Johns Hopkins University, where he also earned B.E. and M.S.E. degrees. He is the author of the leading college textbook on radar, *Introduction to Radar Systems* (McGraw-Hill), now in its second edition, and the editor of *Radar Applications*.

He is a member of the National Academy of Engineering, a Fellow of the IEEE, and has served as editor of the *Proceedings of the IEEE*.

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