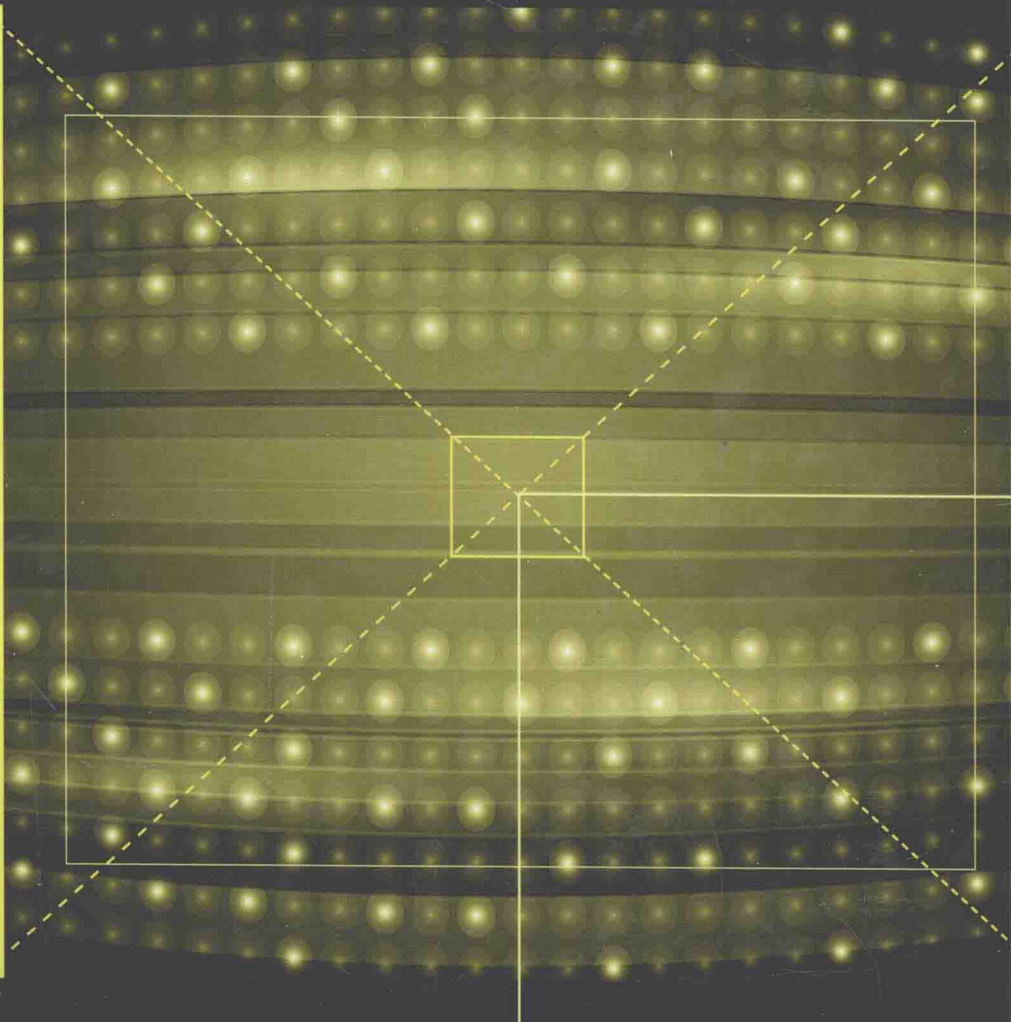
ELECTRONIC WARFARE RECEIVERS AND RECEIVING SYSTEMS

RICHARD A. POISEL



Electronic Warfare Receivers and Receiving Systems

Richard A. Poisel

ARTECH HOUSE
BOSTON | LONDON
artechhouse.com

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the U.S. Library of Congress.

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library.

Cover design by John Gomes

ISBN 13: 978-1-60807-841-7

685 Canton Street
Norwood, MA 02062

10 9 8 7 6 5 4 3 2 1

Electronic Warfare Receivers and Receiving Systems

This book is dedicated to Debbie, Cindy (posthumously), Bruce, Paul, Linda, and Karen. Scotts all, devoted to one another.

Preface

Receiver systems can be considered to be the core of electronic warfare (EW) intercept systems. Without them the fundamental purpose of such systems is null and void. In this work we consider the major elements that make up receiver systems and the receivers that go in them.

Receiver system architectures are introduced in Chapter 1. Basic nomenclature and system functioning are covered, including the key system performance parameters. Spread spectrum signaling is introduced as that, along with non-spread digital signaling, is the foundation of most communication systems in which we are interested. The chapter concludes with an overview of collection management on the battlefield. EW signal collection is but one of many ways information is collected, and it is useful to see where EW fits with some of the other disciplines.

Chapter 2 covers communication signals and the modulation systems they use. Mathematical representations of these signals are introduced. The principal focus is on digital techniques as digital signaling is the basis for modern spread spectrum communications. An introduction to random modulation is provided because most realistic communication signals are contaminated with at least thermal noise and that yields them at least partially stochastic in nature. We introduce the primary spectrum access methods to include the relatively new one, spatial division multiple access. The chapter concludes with a brief discussion of two of the most popular types of signal filtering methods.

Beginning in Chapter 3, we delve into the major elements comprising receivers. Chapter 3 specifically covers the RF stage at the target signal entry point. Major noise sources are considered with particular emphasis on low noise amplifiers. Thermal noise is a particular nemesis because target signals of interest are typically very weak for EW systems. Low noise amplifiers are required to minimize this source of noise. Although the coverage is far from exhaustive, we consider low noise amplifiers designed with both bipolar junction transistors and metal oxide semiconductor transistors. The effects of mismatches between the antenna and receiver input are covered. The chapter concludes by considering band select/preselector filters and why they are required.

The low noise amplifier (LNA) in the receiver RF stage must be as wideband as possible in EW receivers. These receivers typically have a very wide frequency range and usually multiple LNAs. Of course, the more of these amplifiers, the more costly the receiver becomes, both in terms of price and the amount of space occupied by the receivers. In addition, the receiver requires more power, which is usually at a premium. The preselection filters also must be wideband, but usually not as wide as the LNA. Suboctave preselector filters are frequently employed. Relatively narrowband (i.e., 10% of tuned frequency) amplifiers are also used. Thus, in Chapter 4 we introduce some techniques for enhancing the bandwidth of amplifiers.

The next stage in the signals path through the receiver is usually the mixer, which we introduce in Chapter 5. The fundamental parameters are discussed and the limitations on the mixer are covered. Some simple mixers are introduced, concluding with a discussion on the Gilbert mixer, popular for system-on-a-chip receivers. Chapter 5 concludes with a presentation on oscillators. The local oscillator plays a large role in establishing the receiver performance.

The mixer stage usually drives the intermediate frequency (IF) chain, which we introduce in the next two chapters. In Chapter 6 the RF amplifiers used for the IF amplification function are considered. Chapter 7 examines analog filters and their characteristics. These filtering stages are normally narrowband, with the same frequency used irrespective of the RF frequency to which the receiver is tuned.

Analog narrowband receivers, which have formed the majority of EW receivers up until relatively recently, are discussed in Chapter 8. The superheterodyne receiver is introduced along with its popular cousin, the homodyne receiver (which is really a special type of superheterodyne receiver). Tuned radio frequency receivers are briefly mentioned, although they do not comprise a widely used architecture for EW receivers. In some applications they can be used because of their simplicity and therefore low cost.

We consider compressive receiver architectures in Chapter 9. They form a family of architectures that, while being wideband, can detect signals that are changing frequency rapidly, as one type of spread spectrum does, and, coupled with the necessary signal processing, allows for intercept of these signals. The modules that allow for this fast processing are introduced and key performance parameters examined.

Another popular family of wideband receivers useful for processing spread spectrum signals is digital, which we introduce in Chapter 10. This chapter forms an introduction to the following five chapters, which delve deeper into particular topics for digital receivers. Chapter 11 covers the important topic of sampling signals as well as how this is accomplished—with analog-to-digital converters. The principal architectures and performance parameters for analog-to-digital converters are covered. Chapter 12 provides an introduction to digital filters and their performance. Methods for digital demodulation of signals are covered in Chapter 13. Converting signals from the digital domain back into the analog domain is sometimes (although not always) required. These devices and their main architectures are introduced in Chapter 14. Finally, in Chapter 15 we consider direct digital converters, a method of extracting narrowband signals from wideband ones that are comprised of several of the narrowband signals. This is a key requirement of modern wideband EW receiving systems.

The methods of spreading narrowband signals into wideband ones are reviewed in Chapter 16. Direct spread, frequency hopping, and time hopping methods are discussed and their characteristics are assessed.

The next three chapters cover some receiver architectures for these three types of spread spectrum signals. Chapter 17 provides two representative architectures for direct spread signals. The difficulty in intercepting this type of signal should become clear after reading this chapter. Chapter 18 examines some popular digital architectures for intercepting frequency hopping signals, as well as the use of compressive receivers for this purpose. These signals are considerably easier to process. Finally, Chapter 19 illustrates receiver architectures for time hopping signals. The method of accomplishing time hopping consists of using pulse position modulation and very wide bandwidths (several gigahertz). As such, they can easily interfere with many other types of communications if their power is not carefully controlled. Because of this, they are currently limited to very short range links (personal area networks). The receiver architecture that can address this signal type is the time-channelized radiometer, and we discuss that architecture.

We introduce receiver techniques for direction finding in the final chapter, Chapter 20. We examine the architectures for the most popular forms of signal processing and discuss most of the sources of error introduced both internally and externally in EW systems. We conclude the chapter with a brief discussion of using the compressive receiver for this purpose primarily for frequency hopping targets.

Some symbols are duplicated. In a book such as this that covers a wide variety of subjects, it is difficult to avoid reusing symbols and still adhering to common standards (f for both frequency and noise factor, e.g.). While every effort has been made to minimize this, some duplication is unavoidable. In those cases, it is hoped that the meaning of the symbols is clear from the context.

Any errors of commission or omission are the responsibility of the author. As always, constructive feedback is welcomed.

Table of Contents