Preface

It is the purpose of this monograph to demonstrate how state variable concepts can be successfully applied to a variety of problems in communication theory. Although these concepts have become firmly established in modern control theory, their application as discussed in the communication theory literature has not been nearly as extensive. State variable concepts offer at least two advantages to the communication theorist. First, they provide another view into a problem, often one which brings new insight. Second, they often lead to solution procedures that are readily adaptable to the digital computer. In many cases, the methods are not only straightforward to program, but they also often offer significant savings in the actual computation time required.

At first we focus our attention here on their utility in solving integral equations. These equations are of fundamental importance in communication theory; consequently, our concepts and results are useful in a large number of problems of interest. We then consider two specific applications. The first concerns optimal signal design for colored noise channels while the second considers linear estimation theory.

For background we assume that the reader is familiar with detection and estimation theory at a level as discussed by Van Trees (H. L. Van Trees, *Detection, Estimation, and Modulation Theory, Part I,* John Wiley & Sons, Inc., New York, 1968) and with deterministic state variable concepts as discussed by Zadeh and Desoer (L. A Zadeh and C. Desoer, *Linear System Theory*, McGraw-Hill Book Company, Inc., New York, 1966), by Athans and Falb (M. Athans and P. L. Falb, *Optimal Control*, McGraw-Hill Book Company, Inc., New York, 1966), or by DeRusso, Roy, and Close (P. M. DeRusso, R. J. Roy, and C. M. Close, *State Variables for Engineers*, John Wiley & Sons, Inc., New York, 1965). We developed the needed state variable results as related to random processes. A more tutorial development can also be found in Van Trees. When we discuss the estimation problems of smoothing and filtering with delay, we also assume that the reader is familiar with Kalman and Bucy's results on optimal filtering (R. E. Kalman and R. Bucy, "New Results in Linear Filtering and Prediction Theory," *ASME J. Basic Eng.*, **83**, 95–108 (1961)).

This monograph is essentially a revised version of the author's doctoral thesis (A. B. Baggeroer, "State Variables, the Fredholm Theory, and Optimal Communication." Sc.D. Thesis, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass., 1968). In this context it is a pleasure to acknowledge the patient supervision and interest of Professor Harry Van Trees. It is also a pleasure to acknowledge the interest of Professors Wilbur Davenport and William Siebert, who served as readers on my thesis committee.

Several people made valuable contributions to my thesis. I profited greatly from my association with my fellow student Lewis Collins and with Professor Donald Snyder. Discussions with Theodore Cruise have clarified several issues of the material.

Earlier drafts of the material were typed by Miss Camille Tortorici and Mrs. Vera Conwicke, while the final manuscript was done by Mrs. Enid Zollweg. Their efforts are sincerely appreciated.

The work was supported in part by the National Science Foundation, a U.S. Navy Purchasing Contract, and by the Joint Services Electronics Program. I am grateful for this support. The computations were performed at the M.I.T. Computation Center.