in terms of the fanning motion of the caudal fin. Photographs and experimental data reveal the possibilities of some fluid mechanical features familiar to aerodynamicists such as riblets, compliant surfaces, vortex generators, and roughness effects,

Chapter 7, entitled "Swimming by other Methods," treats paddling, whipping, jetting, sweeping, beating, sailing, skating, and wave riding.

Professor Azuma's writing reflects his deep knowledge and enthusiasm for the devices that creatures have invented to cope with their ever-changing environment.

Arnold M. Kuethe
University of Michigan

Engineering Applications of Correlation and Spectral Analysis

Julius S. Bendat and Allan G. Piersol, 2nd Ed., Wiley, New York, 1993, xiv + 458 pp., $69.95.

One of the major engineering applications of correlation and spectral analysis is in the area of random vibration in which theoretical developments and numerical simulation techniques prevail. These developments have been associated with a number of controversies. Different methods can lead to different answers for the same problem [see Ibrahim, "Nonlinear Random Vibration: Experimental Results," *ASME Applied Mechanics Reviews* **44**(10), pp. 423-446, 1991]. Very few researchers appreciate and have been involved in random vibration testing. Experimental investigations provide more physical insight and reveal new phenomena not predicted theoretically, but experimental techniques are not without difficulties and errors. *Engineering Applications of Correlation and Spectral Analysis,* written by two well known authorities in the field, provides valuable information and answers to many questions asked by practical engineers and researchers involved in experimental random testing. This second edition is enlarged and includes the answers to questions such as (1) what data should be collected? (2) what practical problems exist, and how should they be handled? (3) what particular functions should be computed? (4) how should the data be processed to reduce statistical bias and random errors? and (5) how should computed estimates be interpreted to give physically meaningful answers? The book consists of 15 chapters which treat the application of correlation and spectral analysis of stationary and nonstationary random data as applied to linear and nonlinear systems.

The first chapter introduces definitions of different classes of random data, Fourier series and transforms, and response statistics of linear systems. The probabilistic description and amplitude measures are treated in Chapter 2. Related topics such as special probability density functions and statistical errors are well explained. Chapter 3 introduces correlation and spectral density functions and their general interpretations.

The basic relationships for single-input/single-output (SI/SO) problems are developed in Chapter 4. The treatment includes stationary and transient inputs, effects of non-zero mean values, and coherence functions. Similar treatment is given to feedback control systems. Chapter 5 is a direct application of Chapter 4, and it demonstrates the estimation of system frequency response functions based on measured input/output data and the prediction of system response characteristics. The system identification problem is the main objective of this chapter and includes system parameter estimation and errors associated with estimating frequency response functions. Illustrations of errors are demonstrated via practical examples such as a cantilever beam and a free-free panel under wideband random excitation.

Chapter 6 treats different classes of problems related to acoustic-noise and vibration control engineering. It outlines the differences between frequency dispersive and nondispersive propagations, i.e. whether the propagation speed is or is not a function of frequency. Correlation functions, spectra, and other response measurements are developed for nondispersive propagation, input/output data, and output data alone. Another development is given for the case of dispersive propagation, where the propagation velocity is a function of frequency.

Chapters 7 and 8 deal with single-input/multiple-output (SI/MO) and multiple-input/multiple-output (MI/MO) problems, respectively. These include input/output relations in terms of cross-correlations, coherence and multiple coherence functions, and relative time delay. These chapters also include common applications of the analysis procedures such as the problem of source locations in fluids and solids. Chapter 9 deals with the problem of energy-source identification as a major application of MI/MO relationships. The source identification problem is formulated for uncorrelated noise signals. The authors discuss 10 problems usually encountered in the identification of energy source and thus limit the application of the input/output relationship.

Chapter 10 deals with computational algorithms for estimating the relationships of SI/SO and MI/MO which are developed in Chapters 4 and 8. Formulation of models include two-input systems, multiple-input systems, Fourier transforms, and optimum system relationships. The computational algorithms are based on iterative operations which are more convenient than the traditional matrix solutions. The statistical errors in the computational algorithms are discussed in Chapter 11 for estimates of frequency domain quantities. The errors include bias error and random errors and are discussed for SI/SO, MI/SO problems.

The analyses presented in the first 11 chapters are only valid for stationary random processes for which statistical properties are determined by time-averaging operations over a single time history record. Special treatment for nonstationary random data is presented in Chapter 12. This chapter introduces the practical considerations of using only a single record of a nonstationary signal for statistical analysis. The basis concepts of segmented stationary data, continuously nonstationary processes based on the averaging across the ensemble and time-averaging estimates are introduced. The discussion is extended and covers related problems such as statistical estimation errors, optimum averaging time, and curve-fitted estimates. It also includes a survey of different techniques of estimating autospectra including instantaneous autospectrum and time-averaging spectrum. The analysis is supported by a case study of the vibration response of aerospace structures.

The last chapter presents some techniques to analyze the input/output problem of nonlinear systems. The objectives of the data analysis are described in relation to detection of nonlinearity, identification of the type of nonlinearity, and estimate of some statistics. The treatment covers four types of nonlinearities. The types are (1) zero-memory and finite-memory nonlinear systems, (2) bilinear and trilinear systems in a Volterra series, (3) square-law and cubic nonlinear systems, and (4) parallel linear and nonlinear systems. The analysis is demonstrated for single and multi-degree-of-freedom systems. Numerical results obtained from computer simulation of single and multi-degree-of-freedom nonlinear systems are discussed. The authors demonstrate how to determine system physical parameters in proposed nonlinear differential equations of motion. The method is based on (MI/SO) linear analysis approach applied to reverse dynamical systems.

This book is well written and very valuable for researchers and engineers who are involved in random vibration testing and random signal processing. It is also useful for both basic and applied research of a field dominated by theoretical approaches. Chapters 1 through 5, 12, and 13 are convenient for adoption as a graduate course in random vibration only if the instructor is willing to develop homework problems.

Raouf A. Ibrahim
Wayne State University