XXIII. DETECTION AND ESTIMATION THEORY*

Academic and Research Staff

Prof. H. L. Van Trees
Prof. A. B. Baggeroer
Prof. D. L. Snyder

Graduate Students

I. L. Bruyland
A. E. Eckberg
J. E. Evans
T. P. McGarty
J. R. Morrissey

RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

The work of our group is focused upon the development of efficient methods for the processing of analog and digital signals over channels of interest. We shall divide the discussion of our work into three areas.

1. Sonar and Space/Time Processing

There are many situations in which the propagation effects of the channel have a significant effect upon the signals observed. These effects are particularly interesting when the signal propagates through a layered medium, where appreciable distortion and multiple travel paths are often encountered. Current analyses are deterministic and are confined to methods such as ray tracing or mode analysis. While there is a limited number of results available, at present, that involve the characteristics of random processes propagated over these channels, we are investigating several topics in this area of process propagation for the sonar, or underwater, channel where receiver structure implementation is an issue in the analysis.

One of the principal reasons for studying channel models is to develop effective methods for processing data observed over a large set of sensors or array processing. In this context several areas have been investigated.

a. The measurement of an ambient noise field is often a difficult task, since it can require an extensive amount of data processing. In this context Dr. Jack Capon of Lincoln Laboratory, M. I. T., presented a seminar course that highlighted some of the results that the LASA (Large Aperture Seismic Array) has yielded. Research in this area continues for both the seismic and sonar signal fields.

b. State-variable techniques have led to receiver structures that are very useful from an implementation perspective. Early work on extending these techniques to processes with distributed, or space/time, effects were originally discussed in Professor Baggeroer's doctoral thesis.[1] It was apparent then, however, that a much more fundamental analysis of processing signals with distributed effects was warranted. Aspects of this area have been discussed by Professor Snyder in a paper presented to the International Information Theory Conference,[2] and Terrence P. McGarty is pursuing this as a source for a Doctoral thesis topic.

c. Other issues under consideration include the effects of hard-clipping sensor outputs and tracking receivers.

*This work was supported in part by the Joint Services Electronics Programs (U. S. Army, U. S. Navy, and U. S. Air Force) under Contract DA 28-043-AMC-02536(E).

2. Communication Systems

Several particular communication systems have been considered and are still being analyzed. They include the following systems.

a. The predominant disturbance in the VLF communication band (below 30 kHz) is caused by lightning strokes in world-wide storms. The "spiky" nature of the resulting noise leads to several issues in non-Gaussian detection theory. Professor Snyder and several of his Master's thesis students have been analyzing the problems of the effect of this noise on conventional (linear) receivers, the performance of optimal receivers, and procedures for estimating the parameters of the atmospheric noise model.

b. We have had a long association with nonlinear modulation systems and the interest is continuing in some aspects of them. Master's theses for Professor Snyder have been completed in the areas of the performance of systems with oscillator phase instabilities and "click" or cycle skip noise suppression. Areas now under investigation include optimal pre-emphasis networks whose structure is constrained, and issues in the noisy acquisition problem with Fokker-Planck equation techniques used.

c. Several recent theses have discussed issues in the communication of digital signals over noisy channels. In work completed this year, Theodore J. Cruise in his doctoral thesis under Professor Van Trees investigated feedback communication systems with noise in the feedback path.[3] His results lead to a class of suboptimal structures that are asymptotically optimal. Performance is enhanced by the feedback length but not at the level of the noiseless feedback case. In another doctoral thesis supervised by Professor Van Trees, Richard R. Kurth investigated suboptimal receivers for doubly spread channels and the use of distributed state-variable modelling methods.[4] His results indicate a very small performance for some tractable suboptimal systems. His modelling verified some performance aspects of doubly spread channels and the effectiveness of a modal analysis in analyzing distributed communication systems. James E. Evans is working on a method of calculating performance bounds that is applicable to a large class of systems, many of which could not be approached previously. State-variable methods in the modern control theory have been used to approach the problem of designing optimal signals for transmitting over various channels. A rather general formulation was presented in Baggeroer's thesis, and, in his Master's thesis research, John R. Morrissey is analyzing the problem when the channel introduces Doppler spreading.[1]

3. Parametric Estimation (System Identification) and Random Processes

The structure and performance of methods for estimating parameters in imbedded random processes has been a topic under consideration. In his doctoral thesis research Manouchehr S. Mohajeri is investigating structures for estimating the parameters of seismic signals when the signal-to-noise level is low. Ultimately he desires to lower the threshold for discriminating between natural earthquakes and man-made explosions. As reported in Quarterly Progress Report No. 92 (pages 324-333) Baggeroer has derived Barankin bounds for parameters imbedded in the covariance of a random process rather than in the mean. Primary emphasis here is on predicting the threshold behavior for such parameter-estimation methods. Work in both of these areas continues.

Work on problems concerning issues in random processes continues. The work on the use of state-variable methods for solving the often appearing Fredholm integral equations has been completed, while attention is still being directed toward issues in using the Fokker-Planck equation in the analysis of problems of interest.[5]

A. B. Baggeroer

References

1. A. B. Baggeroer, "State Variables, the Fredholm Theory, and Optimal Communications," Sc. D. Thesis, Department of Electrical Engineering, M. I. T., January 1968.

2. E. V. Hoversten and D. L. Snyder, "An Application of State-Variable Estimation Techniques to Signal Detection for the Optical Cloud Channel," a paper presented at the International Symposium on Information Theory, Ellenville, New York, January 28-31, 1969.

3. T. J. Cruise, "Communication Utilizing Feedback Channels," Ph. D. Thesis, Department of Electrical Engineering, M. I. T., January 1969.

4. R. R. Kurth, " Distributed-Parameter State-Variable Techniques Applied to Communication over Dispersive Channels," Sc. D. Thesis, Department of Electrical Engineering, M. I. T., June 1969.

5. A. B. Baggeroer, "A State-Variable Approach to the Solution of Fredholm Integral Equations," IEEE Trans., Vol. IT-15, No. 5, pp. 557-570, September 1969.