COMMUNICATION SCIENCES

AND

ENGINEERING

XXVII. STATISTICAL COMMUNICATION THEORY*

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RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

1. Investigation of Switching Systems

During the past year both static and dynamic analyses have been performed on a class of switching systems which is used to process signals with high efficiency and consequent small size and weight of equipment.[1] This work was done by J. E. Schindall under the supervision of A. G. Bose. This analysis has been primarily concerned with the modulation systems that cause the two-state switching operation. Work has now shifted to circuit designs that are appropriate to realize these modulation systems. Practical constraints, such as minimal size of filtering elements and allowable operating areas for high-power semiconductor switches, often place severe constraints on the selection of a modulation system. These factors will be investigated with the goal of synthesizing practical systems for handling high-power signals with size, weight, and efficiency advantages over existing linear systems.

2. Investigation of Random Processes in Electronic Switching Circuits

When a slowly rising ramp is applied to the input of a regenerative electronic switching circuit, the resulting switching times will be randomly distributed. This randomness, called "jitter," can be a limitation in many applications, such as sampling systems, trigger and comparator circuits, and switching-type modulators.

A model describing the switching-time jitter in the special case of a tunnel diode switching circuit has been obtained by D. E. Nelsen.[2] Work is now under way to determine models describing the random behavior of other types of switches, such as the flip-flop, the Schmidt trigger transistor switches, and the SCR switch. Preliminary measurements indicate that there may be a common mechanism whereby switching-time randomness is related to the more fundamental shot, thermal, and 1/f noise processes occurring in these circuits, even though these circuits have vastly different topologies.[3]

Ultimately, we hope to be able to model the jitter in all types of regenerative switching circuits. With such a capability, the amount of jitter could not only be predicted for a given circuit but also reduced or minimized by proper circuit design.

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3. Recording and Reproduction of Sound

The design of loudspeakers and of recording techniques has remained a controversial and poorly understood area for decades. Standards committees have not been able to agree upon an acceptable design criterion or measurement technique for evaluation of the common loudspeaker. This subject is complicated by the fact that objective criteria are desired for transducers whose ultimate use involves subjective evalution.

A design criterion has been developed by A. G. Bose which makes use of Green's function to produce recordings of sound as they would be heard if reproduced in a room through an ideal transducer. A computer-aided design program has yielded the design of a practical transducer whose performance is subjectively indistinguishable from that of the ideal transducer.[4]

Present work is directed toward relating the newly derived design criterion to previously accepted criteria. The new criterion is based on power spectrum of the radiated sound, whereas previous criteria have focused upon free-field frequency response measurements.

4. Studies in Digital Signal-Processing Techniques

Recent developments have demonstrated that the digital computer is a very powerful signal-processing tool. This study, by J. D. Bruce and his students, will concentrate upon areas such as developing a better understanding of the relationships between the sample interval, the algorithm complexity, and the degree of parallelism incorporated in the processor hardware.

One signal-processing technique of considerable interest is the nonrecursive filter. Such filters have no poles and are important in applications where positive control must be exercised over the time duration of the filter's impulse response. Several techniques for formulating these filters, including a technique based upon simile transforms, will be investigated. In the second area, interest centers around tradeoffs between the desire for complex processing algorithms and simple hardware under constraints of fixed hardware speed and sample intervals. Also to be considered in these studies are the issues of optimum digital filtering and the estimation of parameters of random processes.

5. Generalized Linear Filtering

In 1964, a characterization of nonlinear systems was developed and its application to nonlinear filtering was suggested by A. V. Oppenheim.[5] This approach to nonlinear filtering represented a generalization of the linear filtering problem and appeared to be suited to the nonlinear separation of signals that have been nonadditively combined.

Specific cases of interest, at present, are in the application of this technique to the separation of convolved signals and the separation of multiplied signals. The techniques as they apply to echo removal and to speech processing have been studied by using the Lincoln Laboratory TX-2 computer.[6, 7] Further applications to speech bandwidth compression are being pursued by A. V. Oppenheim during a leave of absence at Lincoln Laboratory, M.I.T. In other areas, the application of this approach to nonlinear filtering to audio volume compression has been successfully demonstrated by T. G. Stockham at Lincoln Laboratory,[8] and the sensitivity of the compressor to additive noise is being investigated.[9]

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