COMMUNICATION SCIENCES
AND
ENGINEERING

XVII. PROCESSING AND TRANSMISSION OF INFORMATION*

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RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

1. Optical Communication

A major part of our group's effort is now concentrated on optical communication. Our objectives are to (i) formulate communication models for optical channels from underlying physical processes, (ii) determine the fundamental limits on the reliability of communication through these channels, (iii) develop communication techniques that enable communication with a reliability approaching these limits, and (iv) establish the validity, and guide the evolution, of the results by experiment.

Our concern is with channels, such as the turbulent atmosphere, clouds or haze, which cannot be used effectively by a straightforward extrapolation of microwave technology to optical wavelengths. The "quantum channel" that must be used to study the ramifications of quantum physics to optical communication is also of major interest to us.

During the coming year our activities will focus on resolving some long-standing fundamental questions in quantum communication, and on utilizing our experimental facilities to better understand the performance of practical implementations of near-optimum systems; a study of imaging radars will also be initiated. Our past experience has indicated that an improved data-processing capability is invaluable in random-channel measurements; accordingly, we plan to upgrade our data-processing capability.

The extent to which "quantum noise" unalterably limits communication at optical frequencies will also be a topic of major concern. The central question to be resolved is whether limitations encountered in the class of systems considered thus far are fundamental in nature or whether they can be circumvented, in principle or practice, by more general signal-generation and measurement schemes.

A second set of investigations will use experimental facilities developed during the past year, particularly the experimental scatter link developed in cooperation with M.I.T. Lincoln Laboratory. Our earlier cw intensity measurements will be augmented by pulse multipath spread measurements after the existing transmitter is

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modified for Q-switching. These measurements will further our understanding of scattering processes in clouds, fog, and haze, as well as in over-the-horizon geometries.

More sophisticated measurements of atmospheric propagation processes will be made possible by our recently developed 9-element array heterodyning receiver. With this instrument the instantaneous amplitude and phase of 9 focal-plane samples of the received field can be measured simultaneously. Such measurements are required to determine field coherence areas. The array receiver will also be used to develop further our earlier theoretical investigations of channel-tracking receivers and transmitters. It will be used first to verify that the signals from the 9 samples can be combined coherently, thereby achieving markedly improved performance over available incoherently combining receivers. Finally, the "receiver" will be operated as a channel-tracking transmitter that predistorts the transmitted beam to compensate for anticipated atmosphere distortion, thereby realizing antenna gains that exceed those allowed by atmospheric seeing.

The performance limitation imposed upon active-imaging radars by the turbulent atmosphere will be the subject of a new investigation. Such radars may be useful for monitoring various earth resources. The plan is first to generalize some previous work on "passive" imaging systems to "active" imaging and to extend those results to include weak-signal quantum effects. Signal design will also be considered.

R. S. Kennedy, E. V. Hoversten

2. Coding for Noisy Channels

Most of the work in the coding area for the past year has been devoted to the theory of branching random walks and applications to sequential decoding. Exact expressions have been derived for the number of particles between absorbing barriers in a branching random walk, and this has led to exact expressions for the mean number of computations per decoded digit for sequential decoding on symmetric channels. These expressions are of limited utility, since they involve the solution of a set of Wiener-Hopf equations. They are amenable to numerical calculation, however, and can be used to check for anomalies in operating sequential decoding systems.

A theory has also been evolved for coupled random walks and branching random walks. This forms the basis for a theory of sequential decoding on nonsymmetric channels. A paper presenting the theory of branching random walks and the applications to sequential decoding is being prepared.

R. G. Gallager

3. Channels, Networks, and Algorithms

Work on simple techniques for encoding analog sources has been largely completed with B. Neumann's[1] doctoral thesis on the use of noiseless feedback in connection with a forward channel with additive non-white Gaussian noise. New investigations deal with networks and corresponding algorithms, for purposes of communication and also for data-processing tasks such as sorting, which are closely related to the problem of connecting N transmitters to N receivers in an arbitrary order. In a doctoral thesis just completed, M. J. Marcus[2] uses information theory techniques to obtain new results for connecting networks and also to analyze some sorting networks. Further work in this area continues. Another new area of investigation is the effect of limited storage capability at intermediate nodes on the traffic-handling capability of a communication network.

P. Elias

4. Theory of Information Storage and Retrieval

In a doctoral thesis, T. A. Welch[3] used information theory models and techniques to explore the relation between the amount of information stored in a library catalog and the relevance, recall and retrieval effort involved in finding facts in the library. Work now in process uses a more formal model of a retrieval system. General lower bounds have been found for the number of bits which must be stored to represent a data base and for the number of bits which must be accessed to answer a question about it. Trading relations between these bounds are being explored.

P. Elias

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3. T. A. Welch, "Bounds on Information Retrieval Efficiency in Static File Structures," Ph. D. Thesis, Department of Electrical Engineering, M. I. T., May 1971.