ENGINEERING RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

APPLICATION OF BASIC SCIENCE TO COUNTERMEASURES RESEARCH

PROGRESS REPORT NO. 18, TASK ORDER NO. EDG-3
Period Covering September 1, 1956 to March 1, 1957

Electronic Defense Group
Department of Electrical Engineering

By: T. G. Birdsall
W. P. Tanner, Jr.
M. P. Ristenbatt
B. Hazeltine

Approved by: A. B. Macnee

Project 2262

TASK ORDER NO. EDG-3
CONTRACT NO. DA-36-039 sc-63203
SIGNAL CORPS, DEPARTMENT OF THE ARMY
DEPARTMENT OF ARMY PROJECT NO. 3-99-04-042
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ABSTRACT

Progress during the eighteenth reporting period is indicated. The experimental effort during the period was directed toward the study of the method of measuring the effectiveness of communication in interference, and the ability of the human observer to detect and recognize signals in noise. The application of the theory of signal detection to more involved problems has been extended, and work has begun on "programming" the scan of a rapid scanning panoramic receiver as a means of apparent search-bandwidth control.

TASK ORDER NO. EDG-3 (Amendment No. 1)

Title: APPLICATION OF BASIC SCIENCE TO COUNTERMEASURES RESEARCH

Starting Date: 1 September 1951 Completion Date: Continuing

Purpose of Task:

To investigate those aspects of science of general interest to the countermeasures field. Emphasis to be placed on those areas of electrical engineering, mathematics, and psychophysics which will contribute to the development of improved equipments and systems.

Investigations carried out under this task will be those required by the task structure of the contract, but not specifically delineated in the individual task description.

Procedure:

a. Applications of statistical analysis to appropriate problems in search and intercept.

b.. Study of problems involving application of psychophysical phenomena.

c. Application of suitable theory and development to design principles for equipments and systems.

d. Recommendations for development of equipments and systems.

e. Solution of problems of a supporting nature necessary to carry out other task assignments but not necessarily specified under those tasks.

f. Performance of special sub-tasks for SCEL not foreseeable at this time, but falling within the general purpose of this task.

g. Preparation of technical reports and memoranda presenting results of investigation in form suitable for direct application by SCEL engineers to the design of equipments and systems.

Personnel:

Evans Signal Laboratory - I. O. Myers

Electronic Defense Group -T. G. Birdsall
W. P. Tanner, Jr.

APPLICATION OF BASIC SCIENCE TO COUNTERMEASURES RESEARCH

PROGRESS REPORT NO. 18, TASK ORDER NO. EDG-3
Period Covering September 1, 1956 to March 1, 1957

1. PURPOSE

The purpose of this report is to outline the progress of Task Order No. EDG-3 under Signal Corps Contract No. DA-36-039 sc-63203 for the period September 1, 1956 to March 1, 1957.

The purpose of Task EDG-3 is to investigate those aspects of general science of general interest to the countermeasures field.

2. REPORTS, TRAVEL AND VISITORS

Preparation of the following reports was completed during this period.

"A Theory of Recognition," by W. P. Tanner, Jr., J. Acoust. Soc. Am., Vol. 28, No. 5, September 1956, p. 882.

Letter to the Editor: "Inapplicability of the Threshold Concept to Detection of Signals in Noise," by R. R. McPherson, was published in the JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA, Vol. 29, No. 1, January 1957.

"Theory of Signal Detectability," was presented by Mr. T. G. Birdsall at the 14th Sonar Conference, U.S. Navy Electronics Laboratory, San Diego, California, November 18-20, 1956.

"On a Formula for Equivalent Number of Independent Noise Samples Per Unit Time," by R. R. McPherson, Electronic Defense Group Technical Memorandum No. 35, University of Michigan, Ann Arbor, Michigan, January 1957.

The following conferences were held during the period covered by this report:

September 6-8, 1956. Thirty visitors attended the Conference on Psychophysical Methods which was held at the University of Michigan, and visited the EDG Laboratories.

September 11, 1956. Messrs. L. B. Young and J. E. Browder, Bendix Aviation Corporation, Detroit, visited the Electronic Defense Group to discuss signal detection work being conducted at EDG.

September 10-20, 1956. Dr. A. B. Macnee and Mr. T. G. Birdsall attended the 1956 Symposium on Information Theory at Massachusetts Institute of Technology.

September 17-19, 1956. Mr. Charles Lombardo, Radio Plane Co, Van Nuy and Mr. William F. Stoehr, Bendix Corporation, Los Angeles, visited EDG to discuss Task EDG-3 and -7.

October,2, 1956. Messrs. Harrington Richer and Lewis Billig, General Electronics Laboratory discussed Tasks EDG-3 and -7 with EDG personnel.

October 8, 1956. Dr. Bruce L. Cusack, New York University and Mr. Alexander N. Beichek, Evans Signal Laboratory, visited EDG to discuss Task EDG-3 work.

October 26, 1956. Mr. Jerome Elkind, Radio Corporation of America, Waltham, Mass. discussed human engineering with EDG personnel.

October 29-30, 1956. Mr. Lars H. Zetterberg, Research Institute of National Defense, Sweden, discussed Tasks EDG-3 and -7 with Dr. Macnee and Messrs. Farris and Tanner.

November 2, 1956. Drs. A. M. Winzemer and Melvin Shakun, Bulova Research and Development Laboratories, Woodside, New York, discussed Task EDG-3 work with W. P. Tanner.

November 6, 1956. Dr. R. L. Shuey, General Electric Company, Schenectady New York, visited EDG to discuss problems of mutual interest in signal detection.

November 12-22, 1956. Mr. W. P. Tanner, Jr., visited Bendix Corporation and Rand Corporation in Los Angeles in connection with Task EDG-3 and attended the Acoustical Society Meeting. He also attended the 14th Sonar Conference at the U.S. Navy Electronics Laboratory, San Diego.

November 18-20, 1956. Mr. T. G. Birdsall attended the 14th Sonar Conference at the U.S. Navy Electronics Laboratory, San Diego, at which he presented a paper entitled: "Theory of Signal Detectability."

November 26-30, 1956. Messrs. Richard Longmire, Richard Laymon and Adrian Pritsker, of Battelle Memorial Institute, Columbus, Ohio, visited EDG to discuss work related to Task EDG-3 and -7.

December 12-13, 1956. Prof. A. B. Macnee and Mr. T. G. Birdsall attended a conference on signal detection at the National Security Agency, Washington, D. C.

January 23, 1957. Dr. John A. Swets, of Massachusetts Institute of Technology, visited EDG as a consultant for Melpar, Inc., and discussed Task EDG-3 work with Messrs. Birdsall and Tanner.

February 22, 1957. Messrs. John E. Bardley and William G. Hardy of Johns Hopkins Medical School visited EDG to discuss Signal Detection with W. P. Tanner, Jr.

3. REPORT ON ACTIVE STUDIES

3.1 Search and Intercept

3.1.1 SIMRAR (Simulated Receiver and Recorder). All of the components of SIMRAR necessary to study the detection of a pulsed carrier of unknown phase and starting time have been completed and preliminary tests made. This is one of the cases for which the optimum detection system can be specified, but the performance of this optimum system, and the effects of deviations from this optimum, are very difficult to calculate. Although the first tests have indicated some mismatch between the input and the output dynamic ranges of the individual units, it appears that this simulation will be successful.

3.1.2 Statistical Models. The statistical model of a broadband non-optimum decision device has been extended to 30 to 120 degrees of freedom. It agrees fairly well with the small-signal detection data of experiment III reported in EDG Technical Report No. 42. It also matches the large-signal intensity recognition data now being taken in this group.

The application of the methods of the theory of signal detectability has been extended to cover two types of problems where a decision at any time will modify the future capability of making positive decisions. The first type has been called the "end of day" problem. The objective in this problem is to maximize the performance from the present time to some specific time in the future; e.g., the end of the day. Only a certain number of positive decisions will be allowed between now and the end of the day. The second type of problem is called the "refractory" problem; i.e., each positive decision renders the receiver ineffective for a fixed refractory time, after which it recovers and renews observation.

The solution of these problems is in terms of a programming of the operating bias level of the receiver; the optimum receiver is that specified by likelihood ratio, as in EDG Technical Report No. 13. The solution also applies to the programming of most non-optimum receivers. The report on this extension should be completed during the next period.

3.1.3 Panoramic Receivers. A background study of component parts for a rapid scanning receiver has been made. This emphasized tunability, frequency coverage, noise figure, and amplification. The objective is to relate the limitations placed on rapid scan receivers by the present state of the art, with the desired specifications as discussed in EDG Technical Report Nos. 3 and 38.

Following this, theoretical work has begun on programming the scanning of such a receiver to obtain variable search-bandwidth control.

3.2 Psychophysics of the Human Observer

The statistical model of the non-optimum broad-band receiver has pointed out a dependence between $\frac{2E}{N_O}$, and the model necessary to describe the observers performance in detection and recognition experiments. This model, along with the postulation of something akin to an automatic tuning device, appears to have made possible a single unified model of the performance of a human being over a large range of detection and recognition experiments.

Large signal studies (i.e., where $2E/N_o$ is a large number) based on the statistical model of the non-optimum broad-band receiver have furnished the basis for this work. The collection of data for this study has been completed, and the writing of the report describing this work is underway.

The report will describe how memory factors for frequency, phase, and amplitude play a role in the observers performance. It will be shown that the observers' efficiency as compared to a mathematical optimum increases as the signal becomes large, reaching a constant when the value of $2E/N_o$ is in the neighborhood of 20.

3.3 Communication Under Interference

The experimental program in this area was directed toward a study of the effect of feedback channels on the communication in the primary channel, and the effect of the measurements of the effectiveness of the primary channel. The type of test used was the "map" test; the feedback channels used were a clear-voice channel, a visual one-bit command channel, and a voice channel with extremely high interference. This last was usually simulated by simply removing the feedback channel. In all "map" testing the effectiveness of the primary channel is measured by the average time to transmit basic messages (routes), the variance of the individual times, and the percentage of messages completely correct. In addition, the different feedback situations change the time required for a team to develop a new transmission style when faced with a new type of interference, and the time required for a team to adapt a transmission style as the interference level varies. Changes in style are important in the use of the tests as a laboratory measure, since they affect the time that must be spent in retraining teams to equilibrium before the test can be used.

4. EQUIPMENT

A rack-mounted random selector was added to the audio map testing gear. It is of the spinning-disc type, and is operated with either a hand or foot switch. It selects 000 to 999 equally-likely routes, displays them for several seconds, and then returns to "spinning". The transmitting observer then enters a rotary card file at the selected number to get the 10-bit message, or route, to be transmitted.

5. FUTURE PROGRAM

The SIMRAR studies will be continued. Construction and testing of the equipment is essentially complete.

A report on statistical models, as applied to the theory of signal detectability, will be written.

The theoretical work on panoramic receivers will continue.

A report based on the large signal data collected in the psychophysics studies will be written.

The communication-under-interference studies will be continued.

A detectability study of the Lincoln F9C System will be initiated.

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