AD-A066 747 TEXAS UNIV AT AUSTIN COMMUNICATIONS THEORY AND SYSTEM--ETC F/G 9/4
MIXTURE RESOLVING SIGNAL PROCESSING WITH APPLICATIONS IN COMMUN--ETC(U)
OCT 67 W D GREGG, C FIESTEL, J KOZUH, K CULP NOBSR-93124

UNCLASSIFIED CTSRL-67-12 NL

1 OF 1
ADA
066747

END
DATE
FILMED
5-79
DDC

THE UNIVERSITY OF TEXAS

DEPARTMENT OF ELECTRICAL ENGINEERING

10 William D. /Gregg, Claude /Fiestel
Joseph /Kozuh Ken /Culp

6

MIXTURE RESOLVING SIGNAL PROCESSING WITH APPLICATIONS IN COMMUNICATIONS/RADAR/SONAR THEORY AND SYSTEMS - THEORY AND EXPERIMENTAL.

Dr. William D. Gregg
Director and Principal Investigator

Communications Theory and Systems
Research Laboratory

9 Interim research summary rept.,

14 Interim Research Summary No. CTSRL-67-12

15 NObsr-93124, AFOSR-67-766

12 22p.

11 20 October 1967

Research sponsored in part by the Department of Defense's Joint Services Electronics Program under Grant AF-AFOSR 766-67 and Naval Ships Systems Command Contract NObsr 93124.

MIXTURE RESOLVING SIGNAL PROCESSING

1. **THEORY** - Professor Wm. D. Gregg, Claude Feistel and Joseph Kozuh,*
Ken Culp, Computer Programmer

Research activity in the area of communication theory and systems pertinent to signal detection, filtering and parametric information extraction is in progress.[1,10] The major effort is concerned with the conception, definition, study, development and interpretation as well as application of techniques relevant to the solution of signal mixtures composed of information and external channel impairment effects typical of communications/radar/sonar environments. Theoretical research has been primarily concerned with the task of performing measurements upon incoming signal mixtures in order to extract required parametric data for optimum processing of the available signal in a detection or extraction context. Approaches and techniques currently under investigation consist of formal mixture decision theory,[6,8] M^{th} order statistical measurements,[2,3,7] and conventional and optimized decision directed estimation.[1,4] In the overall measurement effort, the goal has been to derive a relatively noise-free signal detection/classification/discrimination reference. Rather broad analytical activity in progress has been directed toward the concept of moment estimation[2,3,6,7] in discriminant function synthesis and mixed series resolution. The incoming data models allow for the consideration of non-Gaussian as well as Gaussian statistics. Properties of mixture resolving estimators currently being studied and evaluated consist of measurement bias, mean-square estimation error, measurement variance, and related measures of convergence as a function of observation data available for processing as well as a measure of "signal" field intensity to "noise" field intensity.

In addition, discrete signal processing algorithms are being developed and digital computer programs extended in order to further Monte Carlo experimental case studies. The theoretical development is aimed at the goal of formulating analytical results for optimal mixture resolving signal and data processing structures requisite to the tasks involved in optimum channel identification, phase coherent and matched filter detection, target and cross section identification/discrimination/classification, and multi-function range, doppler, and coordinate resolution, etc.

In particular, two classes of mixture resolving estimators have been treated and compared: 1) a uniformly weighted decision-directed estimator, and 2) an M^{th} order moment estimator.[2] The estimator formulation was developed under the conditions of no a priori classification of the incoming signal mixture observations into isolated data populations, and no a priori knowledge of the mixture population parameters representing the noise covariance and signal waveforms was assumed.

Monte Carlo experimental studies of convergence properties for the binary case were carried out via digital computer simulation. The principal results, observations, and conclusions are as follows: 1) the M^{th} order moment measurement algorithm converges at a rate higher than that of the uniformly weighted decision-directed algorithm; 2) the M^{th} order moment measurement algorithm developed in this work is bounded from above by the uniformly weighted decision-directed algorithm near threshold signal-noise-ratio conditions, and reasonably approaches the performance of the Bayes matched filter. The latter effect is attributed to the fact that moment mixture resolving estimation, as developed, is unbiased whereas uniformly weighted decision-directed mixture resolving estimation contains a signal-noise-ratio dependent bias.

The significance of the increased convergence rate is the generation of a relatively noise free detection reference in shorter time providing for near optimum asymptotic performance. A comparison of experimental results is given in Fig. II-9. Further quantitative results will be presented in the next report.

2. EXPERIMENTAL - Professor Wm. D. Gregg, Bill Boverie, Jimmy Hinton*, and Jimmy Rogers

The abstract and theoretical results for signal-mixture resolution are interpreted into physical terms for purposes of exploiting technological utility in terms of electronic data processing implementation for the design of and physical experimentation with detection/estimation/resolution and information extraction systems. Analog peripheral and special purpose electronics intended for the processing of actual signal mixtures encountered in actual communications/radar/sonar environments are implemented. Experimental research is aimed at a demonstration and evaluation of the stability and convergence characteristics of the various optimal adaptive and learning receiving-systems theoretically developed. The experimentation laboratory is being readied to accomplish near physical simulation studies, scaled at most in frequency, with a portion of the environment of actual signal mixtures encountered, synthesized in the analog portion of the peripheral electronics or obtained from a high quality data-tape-system recording of actual sensor outputs in the field. The execution of complex signal processing requirements will be carried out digitally. Specific instrumentation and peripheral preprocessing has been set up and tested to process signal mixture data as might be encountered in telemetry or radar/sonar environment characteristics of angle coded modulation with a suppressed reference, conveyed over a channel with selective fading and angle instability. Electronic preprocessing equipment and signal conditioning monitoring instrumentation has been procured in part, tested and integrated into the system. In the radar/sonar tapes employing various forms of angle diversity coding, the instrumentation is being readied to adjust the post tape signal processing center frequencies, bandwidths, spectral cutoff characteristics, conversion frequencies, and thresholds, in conjunction with the cognitive data transfer.

Quantitive experimental results will be summarized and reported as available.

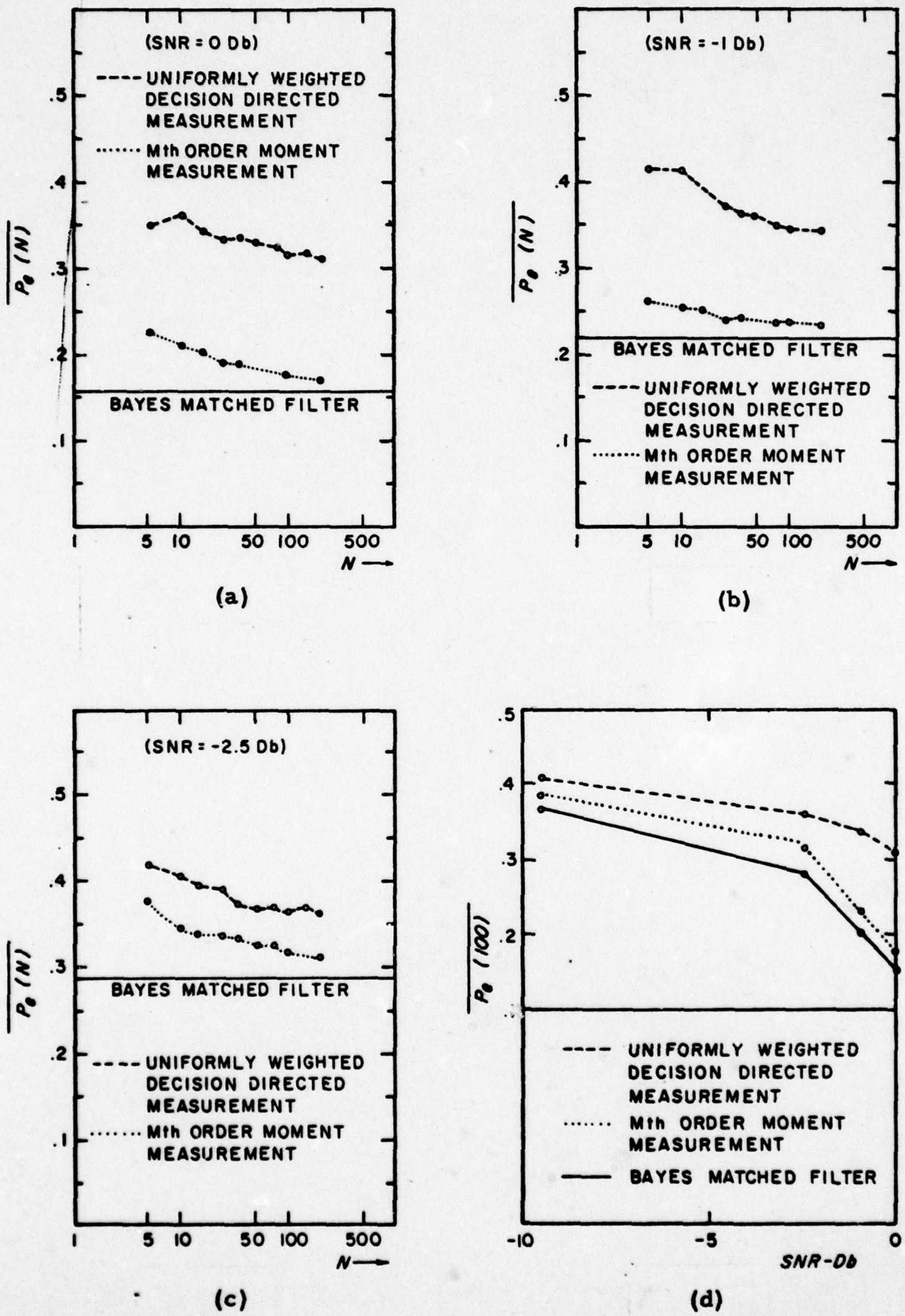

Fig. II-9 Comparison of Experimental Detector Performance Characteristics.

REFERENCES

1. W. D. Gregg, "On the Optimization of Decision Directed Channel Measurements for Coherent Detection," Proceedings of the 1967 Information Theory Colloquium of the Balyai János Mathematical Society, University of Debrecen, Hungary, September, 1967.

2. W. D. Gregg, "A Comparative Study of Mixture Resolving Detectors," Proceedings of the 1967 Information Theory Colloquium of the Bolyai János Mathematical Society," University of Debrecen, Hungary, September, 1967.

3. W. D. Gregg and J. C. Hancock, "Joint Mixture Resolving Estimation and Detection," (accepted for publication in IEEE Information Theory Transactions, Vol. IT-14, No. 1, January, 1968.

4. W. D. Gregg, "A Technique of Optimizing Decision Directed Channel Measurements for Coherent Detection," Southwestern IEEE Conference Record, 20-3-1, April 19, 1967.

5. J. S. Bendat and A. G. Piersol, Measurement and Analysis of Random Data, New York, Wiley, 1966.

6. C. R. Rao, Advanced Statistical Methods in Biometric Research, New York; Wiley and Sons, pp. 300-304, 1952.

7. P. R. Rider, "The Method of Moments Applied to a Mixture of Two Exponential Distributions," Annals of Math. Stat., Vol. 32, pp. 143-147, March, 1961.

8. W. R. Blischke, "Estimation of Parameters of Mixtures of Binomial Distributions," J. of the American Stat. Assoc., Vol. 59, pp. 510-528, 1964.

9. T. W. Anderson, An Introduction to Multivariate Statistical Analysis, New York; Wiley and Sons, 1958.

10. C. R. Rao, Linear Statistical Inference, New York; Wiley and Sons, 1966.

RECEIVER STRUCTURES AND PERFORMANCE CHARACTERISTICS OF OPTIMIZED ARRAY AND DIVERSITY RECEIVING SYSTEMS, Professor W. D. Gregg and J. H. Derryberry*

The multilink array or space diversity receiver structure for the optimum detection of incoming time-varying faded, multipath signals in an additive noise masking environment is derived from the maximum likelihood ratio. This analytical result and consequently the optimum receiver structure is directly related to the model that one chooses for the channel environment. For cases in which the channel has multiplicative fading (random channel modulation), additive noise, and multipath the optimum diversity receiver consists basically of a tapped delay line estimator-correlator computer. This structure has been developed for the case of independent fading and noise multipath fields.[3,4,6]

For problems of engineering interest in communication/radar/and sonar, these fields are often correlated, both between and within the multiple channels and likewise diversity links.[1,2] A study of performance characteristics of optimum receiver processors yields information concerning the relative merit of various modulation formats, combining techniques, and array structures.

This study investigates the effect of cross-link and intra-link correlation of the masking fields, of the array structure, and of the combining technique, upon the system performance for a multipath channel model with diversity reception in which there are correlated fading fields and correlated additive noise fields.

Starting with the development of Price and Green[3,4] and Kailath[5,6] and extending it to the continuous channel model one arrives at the optimum continuous receiver data processor. The receiver processor consists of a bank of estimator-

"auto-correlators" and estimator-"cross-correlators." The structure of each estimator is dependent on the second moment statistical nature of the incident channel processes. The test statistic computed by the receiver, thus contains information about the incident field statistics as well as the diversity array structure. From the test statistic and the receiving system is obtained the associated probability densities and the resulting system performance characteristic. By examining the performance characteristics one observes the effect of the correlation of the random fields and the effect of the array structure on system performance. With this knowledge one draws conclusions as to the advantages and disadvantages of various array structures (those that cause the input data to the processor to be correlated between links and those that cause the link processes to be uncorrelated), optimality of related modulation techniques (PSK, FSK, general angle coding), and various combining schemes (sum, weighted sum, quadratic, etc.)

An extension of the discrete case to the continuous case follows when the discrete filters are replaced by their continuous analog versions. Once this is done continuous analog receiving systems can be investigated for the nature of a similar set of combining, array, and diversity modulation techniques, thus enabling one to design and implement better, more accurate communications/radar/ and sonar detection, classification and discrimination systems. The quantitative results will be summarized and presented in the next report.

REFERENCES

1. H. Makino and K. Morita, "Design of Space Diversity Receiving and Transmitting Systems for Line-of-Sight Microwave Links," IEEE Transactions on Communications Tech., Vol. COM-15, No. 4, August, 1967.

2. J. W. Boyhan, "A New Forward Acting Prediction Combiner," IEEE Transactions on Communication Technology, Vol. COM-15, No. 5, October, 1967.

3. David Middleton, Introduction to Statistical Communication Theory, New York, McGraw-Hill, 1960.

4. M. Schwartz, W. R. Bennett, and S. Stein, Communications Systems and Techniques, New York, McGraw-Hill, 1966.

5. Evan Selin, Detection Theory, Princeton, Princeton University Press, 1965.

6. J. C. Hancock and Paul A. Mintz, Signal Detection Theory, New York, McGraw-Hill, 1966.

7. Kenneth S. Miller, Multidimensional Gaussian Distributions, New York, Wiley, 1964.

OPTIMIZATION OF THE DETECTABILITY OF ARRAY AND DIVERSITY RECEIVING SYSTEMS, Professor William D. Gregg and Robert W. Cline *

Optimum array and diversity reception principles and detectability characteristics[1,2] are being studied and developed to establish the role of a priori information requirements and detectability gain sensitivity to transmitter, channel, cross-section, information mismatches. Initially, the detectability characteristics of a simple one sensor element were examined for the binary signal case.[3] The probability of error, p_E, a figure of performance merit for likelihood detectors was derived and its dependence upon signal to noise ratio for various values of binary signal inter-correlation coefficients was considered. All of the parameters present in p_E were examined with respect to sensitivity and inter-relationships. The model was later modified to include the effect of receiver to channel mismatch conditions.

Proceeding into a more realistic and physically representative problem requires the transition from the discrete case to the continuous case. This transition requires the employment of orthogonal expansions such as the Karhunen-Loeve Expansion[4] and related applications to a wide class of detection problems. In the multiple sensor configuration, the role of the dimensionality of the link upon the test statistic is being enlarged and evaluated. To enhance the "signal-to-noise" ratio, an array of elements is being considered.[5] The number of elements, geometry of the array and spatial field intensity conditions are being examined with respect to their effect upon the overall optimization of the receiver. Means of enhancing space, time, frequency and decision diversities are of related interest.

A figure of merit equation is being derived. Other factors such as time-varying fading, correlation between elements of the array and the role of sensitivity to a priori information requirements are included. Based on the assumption that certain array sensor output spectral properties are desirable, from an optimum detection standpoint, means of enhancing them by variations in the parameters of the array (such as beam steering), etc., are included in the investigation. The intent of spatial processing is to establish the necessary preliminary processing for the purposes of enhancing spatial signal to noise field intensity and relative correlation properties.

Quantitative results will be summarized and presented in the next report.

REFERENCES

1. Franz B. Tuteur, "On the Detection of Transiting Broadband Targets in Noise of Uncertain Level," IEEE Transactions on Communication Technology, Vol. COM-15, No. 1, pp. 61-64, February, 1967.

2. Franz B.Tuteur, "Detectability of Directional Amplitude Modulated Noise Signals in an Isotropic Noise Background of Unknown Power Level," IEEE Transactions on Information Theory, Vol. IT-11, No. 4, (correspondence) pp. 591-593, October, 1965.

3. John C. Hancock and Paul A. Wintz, Signal Detection Theory, McGraw-Hill, 1966.

4. Ivan Selin, Detection Theory, Princeton University Press, 1965.

5. R. C. Hansen, "Microwave Scanning Antennas," Vol. II, Array Theory and Practice, Academic Press, 1966.

6. Edoardo Mosca, "Sidelobe Reduction in Phase Coded Pulse Compression Radars," IEEE Transactions on Information Theory, Vol. IT-13, No. 1, (Correspondence), pp. 131-134, January, 1967.

7. N. Thomas Gaarder, "The Design of Point Detector Arrays I," IEEE Transactions on Information Theory, Vol. IT-13, No. 1, pp. 42-50, January, 1967.

8. N. Thomas Gaarder, "The Design of Point Detector Arrays, II," IEEE-Vol. IT-6, pp. 112-120, April, 1966.

9. Harry Van Trees, Detection, Estimation and Modulation Theory, John Wiley, (to be published).

OPTIMUM DEMODULATION AND INFORMATION EXTRACTION FOR CONTINUOUS TIME FUNCTIONS UNDER BROAD CHANNEL IMPAIRMENT CONDITIONS, Professor William D. Gregg and Stephen Lyons

This research is concerned with the optimal recovery of a continuous message source, $a(t)$, from a masked incident signal, $r(t)$. $a(t)$ may be contained in the carrier's instantaneous amplitude, envelope, angle, frequency or some derivative thereof. Van Trees[1] has investigated the problem in some detail for the nonstationary Gaussian signal source when the carrier is subjected to a randomly time varying channel with additive Gaussian noise. He found that the receiver structure for the "maximum likelihood" estimator requires the implementation of a generally unsoluable integral equation which he interprets as a feedback system with non-realizable filters. This receiver is realized arbitrarily closely by the addition of delay into the system.

The problem has been extended to include additional masking of the message source. Prior to reaching the receiver system the carrier $s(t,a(t))$ may be subjected not only to fading and additive Gaussian noise but also to frequency and phase instability, deterministic jamming and additive impulsive noise (see Fig. II-8). For example with a phase modulated carrier

$$s(t,a(t)) = V(t) \sin (\omega_c t + a(t)),$$

The incident signal $r(t)$ will be of the form

$$r(t) = Ab(t) \sin(\omega_c t + a(t) + \theta(t)) + n(t) + J(t)$$

where

$b(t)$ = fading due to the channel,

$\theta(t)$ = phase, frequency instability, doppler, n(t) = Gaussian and impulsive noise effects, and

J(t) = jamming factor

Current research activity is being concentrated upon the following 1) development of the optimal structure for angle and envelope modulation subjected to fading and phase/frequency instability; evaluation of the optimality measure, and for the optimal instantaneous angle and envelope extractor.[2] Determination of the necessary changes in the optimality criterion and receiver structure when unwanted deterministic clutter is included in the incoming signal. Establishment of the effects of additive impulsive noise upon the system performance and necessary system changes to compensate for it. The effects of phase and frequency instability upon the estimation of a(t) has been developed as a parallel extension of the work of Berger and Tufts[2] for the effects of jitter upon PAM recovery.

Quantitative results will be summarized and presented in the next report.

REFERENCES

1. H. L. Van Trees, "Analog Communication Over Randomly-Time-Varying Channels," IEEE Transactions on Information Theory, pp. 51-63, Jan., 1966.

2. T. Berger and D. W. Tufts, "Optimum Pulse Amplitude Modulation," Parts I and II, IEEE Transactions on Information Theory, pp. 196-216, April, 1967.

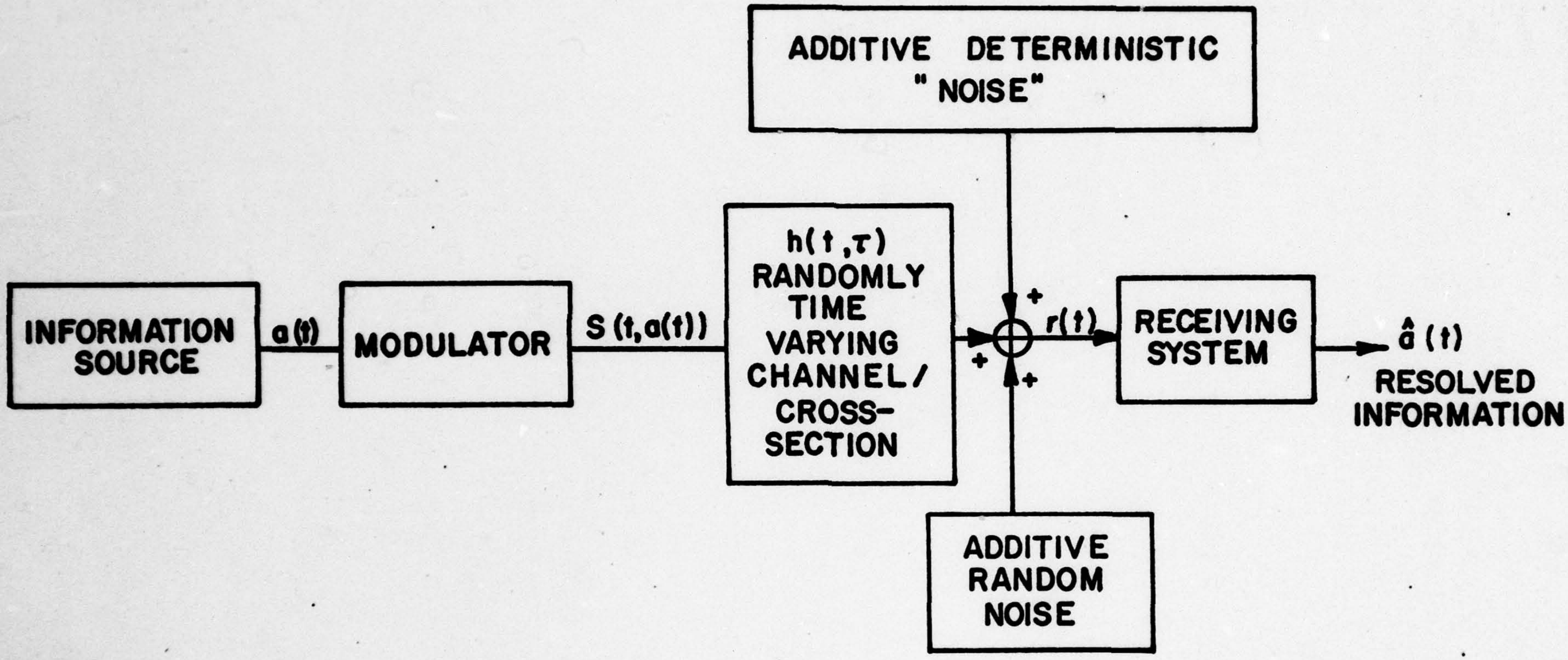
INFORMATION SOURCE
a(t)
MODULATOR
S (t, a(t))
h(t, τ) RANDOMLY TIME VARYING CHANNEL / CROSS-SECTION
ADDITIVE DETERMINISTIC "NOISE"
+
+
+
r(t)
ADDITIVE RANDOM NOISE
RECEIVING SYSTEM
â (t)
RESOLVED INFORMATION

FIGURE II-8

OPTIMAL SIGNAL DESIGN FOR FADING INCOHERENT CHANNELS,

Professor William D. Gregg and Albert J. Berni

The optimization of linear and non-linear "chirp" modulation signals for digital data transmission and reception over coherent and incoherent channels is being investigated.[1,2,3] A study has been made of existing techniques for joint optimization in the transmission and reception of signals of the character stated above.[4,5] For coherent reception in additive noise, the antipodal phase shift keyed signal sets are optimum. When the channel impairments are complicated with multiplicative fading and multipath, incoherent reception with an orthogonal signal set such as frequency shift keying becomes an essential consideration.

Presently being investigated is a compromise between the orthogonal and antipodal signal sets in the form of linear and nonlinear FM'd sets such as slope shift keying. In signals of this nature the frequency modulation is of piecewise continuous type as opposed to the "instantaneous" shifting used in FSK, PSK, etc. Under investigation is the synthesis of an optimum "chirp" like signal set to modulate the frequency in an R.F. transmission with maximum "antipodality." As a first attempt, "piecewise linear" frequency modulation signals are being considered and extended to "quadratic" frequency modulation functions.

Quantitative results will be summarized and presented in the next report.

REFERENCES

1. D. L. Schilling and Edwin Hoffman, "Error Rates for Digital Signal Demodulated by an F. M. Discriminator," IEEE Transactions on Communication Technology, pp. 507-517, August, 1967.

2. W. C. Lindsey, "Design of Block-Coded Communication Systems," IEEE Transactions on Communication Technology, pp. 525-534, August, 1967.

3. S. Stein, "Unified Analysis of Certain Coherent and Noncoherent Binary Communication Systems," IRE Transactions, Vol. CS-10, No. 4, p. 336, December, 1962.

4. J. C. Hancock and P. A. Wintz, "Signal Detection Theory," McGraw-Hill Company, New York, 1966.

5. M. Schwartz, W. R. Bennett and S. Stein, "Communication Systems and Techniques," McGraw-Hill Company, New York, 1966.

RESEARCH ASSISTANTS

1. **ALBERT J. BERNI**, Research Engineering Assistant I

Education:	B.S.E.E.	Newark College of Engineering	1967
	M.S.E.E.	The University of Texas	1968

Experience: Research Engineering Assistant I - Communications Theory & Systems Research Group, The University of Texas, June '67 to present.

2. **ROBERT W. CLINE**, Research Engineering Assistant III

Education:	B.S.E.E.	University of Southwestern LA	1960
	M.S.E.E.	University of Southwestern LA	1963
	Ph.D.	The University of Texas	1968

Experience: Research Engineering Assistant III - Communications Theory & Systems Research Group - June '66 to present
Assistant Professor, E.E. - University of Southwestern LA, September '64 to June '66.
Instructor, E.E. University of Southwestern LA, September '63 to September '64
Systems Engineer - U.S. Naval Ordnance Lab., Corona, California, Summer '62, '63, '64.
Teaching Assistant, University of Southwestern LA September '61 - June '63.
Marketing Engineer, Westinghouse Air Arm Division Baltimore, Maryland, June '60 - September '61.
USAF, Ground Weather Systems Operations, December '52 - September '56.

3. **SAMUEL K. CULP**, Research Engineering Assistant I

Education:	M.S.E.E.	The University of Texas	1968

Experience: Research Engineering Assistant I, Communications Theory & Systems Research Group, February 1967 - present.
Program Debugging - May '66 - September '66 - Houston, Texas, for Pan American Petroleum Corporation, 500 Jefferson Building, Houston, Texas.

4. JIM H. DERRYBERRY, Research Engineering Assistant I

Education:	B. S. E. E.	The University of Texas	1967
	M. S. E. E.	The University of Texas	1968

Experience: Research Engineering Assistant I, Communications Theory & Systems Group and Teaching Assistant, U. T., June '67 to present.
Teaching Assistant, Department of Electrical Engineering September '66 - June '67.
Systems Design Engineer, Ethyl Corporation, Baton Rouge, Louisiana, June '66 - September '66.
Research Engineer, Dallas Power & Light, Dallas, Texas, June '65 - September '65.

5. JOSEPH A. KOZUH, Research Scientist Assistant II

Education:	B. A. Math.	University of Dayton	1965
	M. A. Math.	The University of Texas	1967
	Ph. D. E. E.	The University of Texas	1969

Experience: Research Scientist Assistant II - Communications Theory & Systems Research Group, U. T., June '67 - present.
Teaching Assistant, Department of Mathematics, U. T., September '65 - June '67.

6. STEPHEN MARK LYONS, Research Engineering Assistant II

Education:	B. S. E. E.	University of Kentucky	1963
	M. S. E. E.	University of Illinois	1964
	Ph. D.	The University of Texas	1969

Experience: Research Engineering Assistant II, Communications Theory & Systems Research Group, U. T., January '67 to present.
Instrumentation Systems Engineer, IBM, September '64- January '67 (Saturn).

7. BILL BOVERIE, Research Engineering Assistant II

Education:	B. S. E. E.	Texas Technological College	1960
	M. S. E. E.	University of Maryland	1964
	Ph. D.	The University of Texas	1969

Experience: Research Engineering Assistant II - Communications Theory & Systems Research Group, U. T., September '67 to present.
Engineer, Texas Instruments, Missile and Ordnance Systems Department, Dallas, Texas, September '66 to September '67.
Engineer, Raytheon, Guidance & Fuzing Department, Bedford, Mass., December '64 to September '66.
Engineer, Westinghouse, Advanced Development Dept., Baltimore, Md., June '60 to November '64.

8. CLAUDE FEISTEL, Research Engineering Assistant II

Education:	B. S. E. E.	The University of Texas	1965
	M. S. E. E,	The University of Texas	January - 1969

Experience: Research Engineering Assistant II - Communications Theory & Systems Research Group, U. T., September '67 to present.
Engineer-Scientist, Instrumentation Design Section, Navigation, Communication, Radar, Sonar Systems, Tracor, Inc., Austin, June 1961 to present.

9. JIMMY H. HINTON, Research Engineering Assistant II

Education:	B. S. E. E.	Texas A & M University	1960
	M. S. E. E.	Texas A & M University	1962
	Ph. D.	The University of Texas	1969

Experience: Research Engineering Assistant II - Communications Theory & Systems Research Group, U. T., September '67 to present.
Research Engineering Associate IV, Radar Physics Section, Defense Research Laboratory, Austin, Texas, June '65 to present.
Electronic Systems Engineer, Radar Transmitters, LTV Electrosystems, Dallas, Texas, June '62 to May '65.
Teaching Assistant, Texas A & M University, 1960 - 62.
Electronics Engineer, Naval Ordnance Labs., Corona, California; summer 1961.

10. JIMMY D. ROGERS, Research Engineering Assistant II

<u>Education:</u>	B.S.E.E.	Southern Methodist University	1961
	M.S.E.E.	New York University	1964
	Ph.D.	The University of Texas	1970

<u>Experience:</u>

Research Engineering Assistant II, Communications Theory & Systems Research Group, U.T., September '67 to present.

Senior Electronics Engineer, Continental Electronics, Dallas, Texas, Radar and R&D Dept., November '66 to September '67.

Electronics Engineer, Continental Electronics, Dallas, Texas, R&D, July '62 to November '66.

Member of Technical Staff, Bell Telephone Laboratories, Whippany, New Jersey, Electronic Switching Systems Department, June '61 to July '62.