

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 2/18/97	3. REPORT TYPE AND DATES COVERED Final 6/1/95 - 9/30/96	
4. TITLE AND SUBTITLE Advanced Signal Processing Techniques for Wireless Communication			5. FUNDING NUMBERS N00014-95-1-0834	
6. AUTHOR(S) Prof. Gregory W. Wornell			1313148	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Research Laboratory of Electronics Massachusetts Institute of Technology 77 Massachusetts Avenue Cambridge, MA 02139			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research Ballston Tower One 800 North Quincy Street Arlington, VA 22217-5660			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)			19970224 007	
14. SUBJECT TERMS			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

Final Report for
ONR Grant No. N00014-95-1-0834
Advanced Signal Processing Techniques
for Wireless Communications
for the period
June 1, 1995 through September 30, 1996
Principal Investigator: Prof. Gregory W. Wornell
Research Laboratory of Electronics
Massachusetts Institute of Technology
Cambridge, MA 02139-4307

Research under this grant led to a number of new and promising developments in the use of signal processing methodology and algorithms—including multirate system theory—in the solution of wireless and related communication problems.

In one component, we developed novel bandwidth-efficient temporal diversity strategies for single- and multi-user wireless communication in time-selective multipath fading environments. Both frequency selective and frequency nonselective channels were considered. These multiple-access protocols we referred to as spread-signature CDMA.

We also developed powerful new algorithms for equalization and demodulation in conventional and spread-signature CDMA wireless systems. These algorithms efficiently suppress both intersymbol and interuser (multiple-access) interference.

In other aspects of the research, we developed a closely related class of computation- and bandwidth-efficient techniques for exploiting spatial diversity at the transmitter in wireless systems, which are useful either alone or in conjunction with other forms of diversity.

Another component of the research program explored applications of nonlinear dynamics and chaos in the design of error-correcting codes for communications applications, and the use of fractal traffic models in the design and management of efficient, next-generation packet-switched communication networks. Still other work explored efficient iterative algorithms and performance limits for both single-user and packet-switched communications over channels with feedback.

All these results are described in detail in the following publications, which consist of journal articles, conference papers, technical reports, and student theses.

1. G. W. Wornell, "Spread-Signature CDMA: Efficient Multiuser Communication in the Presence of Fading," *IEEE Trans. Inform. Theory*, vol. 41, no. 5, pp. 1418–1438, Sept. 1995.
2. S. H. Isabelle and G. W. Wornell, "Statistical Analysis and Spectral Estimation Techniques for One-Dimensional Chaotic Signals," to appear in *IEEE Trans. Signal Processing*, submitted Aug. 1995. Accepted for publication Dec. 1996.
3. G. W. Wornell, "Efficient Multiuser Communication in the Presence of Fading," in *Proc. IEEE Int. Sympo. Inform. Theory*, (Whistler, Canada), Sept. 1995. (long presentation)

4. G. W. Wornell, "Spread-Response Precoding for Communication over Fading Channels," *IEEE Trans. Inform. Theory*, vol. 42, no. 2, pp. 488-501, Mar. 1996.
5. W. M. Lam and G. W. Wornell, "Multiscale Representation and Estimation of Fractal Point Processes," *IEEE Trans. Signal Processing*, vol. 43, no. 11, pp. 2606-2617, Nov. 1995.
6. G. W. Wornell, "Emerging Applications of Multirate Signal Processing and Wavelets in Digital Communications," in *Proc. IEEE*, Special Issue on Applications of Wavelets (invited paper), vol. 84, no. 4, pp. 586-603, Apr. 1996.
7. G. W. Wornell and M. D. Trott, "Efficient Signal Processing Techniques for Exploiting Transmit Antenna Diversity on Fading Channels," in *IEEE Trans. Signal Processing*, Special Issue on Signal Processing Advances in Communications, Jan. 1997.
8. G. W. Wornell and M. D. Trott, "Signal Processing Techniques for Efficient Use of Transmit Diversity in Wireless Communications," in *Proc. Int. Conf. Acoust., Speech, Signal Processing*, (Atlanta), May 1996. (invited paper)
9. W. M. Lam and G. W. Wornell, "Multiscale Analysis of Fractal Point Processes and Queues," in *Proc. Int. Conf. Acoust., Speech, Signal Processing*, (Atlanta), May 1996.
10. Chen, Brian, "Efficient Communication over Additive White Gaussian Noise and Intersymbol Interference Channels Using Chaotic Sequences," S.M. Thesis, MIT, Cambridge, MA, Feb. 1996. Also as RLE Technical Report No. 598, Research Laboratory of Electronics, MIT, Cambridge, MA, April 1996.
11. Beheshti, Soosan, "Techniques for Enhancing the Performance of Communication Systems Employing Spread-Response Precoding," S.M. Thesis, MIT, Cambridge, MA, Feb. 1996.
12. A. Narula, M. D. Trott, and G. W. Wornell, "Information-Theoretic Analysis of Multiple-Antenna Transmission Diversity for Fading Channels," in *Proc. Int. Symp. Inform. Theory and Appl.* (Victoria, Canada), Sept. 1996.

13. B. Chen and G. W. Wornell, "Efficient Channel Coding for Analog Sources using Chaotic Systems" in *Proc. IEEE GLOBECOM*, (London), Nov. 1996.
14. J. M. Ooi and G. W. Wornell, "Decentralized Control of a Multiple Access Broadcast Channel: Performance Bounds," in *Proc. Int. Conf. Dec. Control*, (Japan), Dec. 1996.
15. J. M. Ooi and G. W. Wornell, "Fast Iterative Coding Techniques for Feedback Channels," submitted Oct. 1996 to *IEEE Trans. Inform. Theory*. Also as RLE Technical Report No. 613, Research Laboratory of Electronics, MIT, Cambridge, MA, Dec. 1996.
16. A. Narula, M. D. Trott, and G. W. Wornell, "Information-Theoretic Analysis of Multiple-Antenna Transmission Diversity," submitted Nov. 1996 to *IEEE Trans. Inform. Theory*, Nov. 1996.
17. S. H. Isabelle and G. W. Wornell, "Recursive Multiuser Equalization for CDMA Systems in Fading Environments," in *Proc. Allerton Conf. Commun. Contr., Signal Processing*, (Illinois), Oct. 1996.
18. B. Chen and G. W. Wornell, "Analog Error-Correcting Codes based on Chaotic Dynamical Systems," submitted to *IEEE Trans. Commun.*, Dec. 1996.
19. S. Beheshti and G. W. Wornell, "Iterative Interference Cancellation and Decoding for Spread-Signature CDMA Systems," to appear in *Proc. Vehic. Tech. Conf.*, (Phoenix), May 1997.

ATTACHMENT NUMBER 1REPORTS AND REPORT DISTRIBUTIONREPORT TYPES

- (a) Performance (Technical) Report(s) (Include letter report(s))
Frequency: Semiannual
- (b) Final Technical Report, issued at completion of Grant.
- (c) Final Financial Status Report (SF 269)
- (d) Final Patent Report (DD882)

REPORTS DISTRIBUTION

<u>ADDRESSEES</u>	<u>REPORT TYPES</u>	<u>NUMBER OF COPIES</u>
PROGRAM MANAGER/OFFICER ONR: 313 Rabinder N. Madan OFFICE OF NAVAL RESEARCH BALLSTON TOWER ONE 800 NORTH QUINCY STREET ARLINGTON, VIRGINIA 22217-5660	(a) & (b)	3
ADMINISTRATIVE GRANTS OFFICER OFFICE OF NAVAL RESEARCH REGIONAL OFFICE (c) & (d) ROOM 103 495 SUMMER STREET BOSTON MA 02210-2109	(a), (b), (c) & (d)	1
DIRECTOR, NAVAL RESEARCH LABORATORY ATTN: Code 2627 WASHINGTON, DC 20375	(a) & (b)	1
DEFENSE TECHNICAL INFORMATION CENTER BUILDING 5, CAMERON STATION ALEXANDRIA, VIRGINIA 22304-6145	(a) & (b)	2
OFFICE OF NAVAL RESEARCH BALLSTON TOWER ONE ATTN ONR OOC1 MR WILLIAM F MCCARTHY 800 NORTH QUINCY STREET ARLINGTON, VIRGINIA 22217-5660	(d)	1

If the Program Manager/Officer directs, the Grantee shall make additional distribution of technical reports in accordance with a supplemental distribution list provided by the Program Manager/Officer. The supplemental distribution list shall not exceed 250 addresses.