

# CMRR Report

Center for Magnetic Recording Research

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Catherine A. French

## CMRR Confers Ph.D. Degree

In October, the Center conferred a Ph.D. degree on Catherine A. French, a student in the department of Electrical and Computer Engineering at UCSD. She is the first student who has completed all of her doctoral studies at the Center. Her thesis is entitled "Signal Processing for Digital Magnetic Recording Channels." She has been working with Professor Jack K. Wolf at CMRR since July, 1985. French has a B.S. in electrical engineering from the University of Idaho (1982), and an M.S. in engineering from the University of California, Davis (1984). She spent approximately two years in industry, working for IBM in Tucson, Arizona and for Kodak Research Laboratories in San Diego. French will continue at CMRR as a postdoctoral researcher until December, and will join the faculty at the University of Idaho in January.

Here at CMRR, Dr. French's research has been in the general area of signal processing for digital magnetic recording. Specifically, she has co-authored a paper with Professor Wolf and Glenn Dixon (a CMRR M.S. student), on the topic of non-binary signaling and corresponding run-length coding for recording channels. This paper, entitled "Results involving (d,k) constrained M-ary codes" was presented at INTERMAG '87 in Tokyo last April. A related paper with the same co-authors entitled "Signalling with Special Run-Length Constraints for a Digital Recording Channel" will be presented at the International Conference on Video, Audio and Data Recording next spring.

Another topic that French has been studying involves determining the information theoretic capacity of the recording channel. Upper and lower bounds on the channel capacity have been calculated, using a linear filter model with a peak constrained input, and with non-white Gaussian noise at the output.

One other area that Dr. French is exploring is that of equalization for recording channels. Optimum as well as sub-optimum schemes (such as partial response) are under investigation.

## NSF Grants Awarded

Two grants from the National Science Foundation (NSF) have been awarded to Professors Wolf and Talke respectively. The grant to Professor Jack Wolf will support his research on modulation and coding for the magnetic recording channel. The award for the first year is \$91,293 effective from September 15, 1987. This is a continuing grant which has been approved on scientific/technical grounds for three years. Contingent on the availability of funds and the scientific progress of the project, NSF expects to continue support at approximately the following levels: second year \$97,094, third year \$92,891.

The research includes both experimental and theoretical studies. The objective is to increase the density of recording without sacrificing reliability. The work includes research on new modulation codes, new error correcting codes, combined modulation/coding systems and experiments designed to prove the validity of these concepts.

The grant to Professor Frank Talke will support his work on wear and boundary lubrication of oxide coated hard disks. The award for the first year is \$86,000 effective August 1, 1987. Depending on the availability of funding, NSF expects to continue the grant for two further years at the \$80,000 level.

During this year the award will support two students, Douglas Trauner, a senior in the AMES department and Yuanhui Hu, a graduate student also in the AMES department. Hu will work on the measurement of thin lubricant films using ellipsometry, and the effect of slider disk interactions during start-stop on the lubricant thickness in the wear track region. Trauner's research will study friction between head and disk and the material interactions and wear of both slider and disk.

## CMRR Welcomes New Sponsor

CMRR welcomes a new sponsor to its growing list of industrial supporters. Storage Technology of Louisville, Colorado has become CMRR's sixteenth industrial sponsor. Storagetek, a high end storage products manufacturer has been in business for eighteen years and markets a full product line of 1/2" tapes, high performance disc files and system printers.

Dr. William B. Phillips, vice president for advanced technology, will serve as Storagetek's liaison with the Center.



## From the Director

It is my pleasure to announce that finally CMRR's efforts with the National Science Foundation have borne fruit. Within the last three months, the NSF has announced that CMRR is to receive a \$550,000 per year grant in order to create a Materials Research Group, headed by Ami Berkowitz. Additionally, two

other CMRR professors have been awarded individual research grants: Frank Talke and Jack Wolf each get approximately \$90,000 per year. More detail on these grants may be found elsewhere in this *Report*. The long sought after three-way symbiosis between the University of California, the federal government and the magnetic recording industry has finally become a reality!

I am pleased also to announce that Storagetek has become CMRR's sixteenth industrial sponsor. It seems likely, moreover, that we shall recruit one or two more sponsors before the end of 1987.

John Mallinson



Ami Berkowitz

## ECC Workshop at IBM Almaden

On September 14 and 15, 1987, Jack Wolf, one of CMRR's four endowed professors, and four of his graduate students attended a workshop on error correcting coding at IBM's Almaden Research Laboratory. The group gave a one-hour presentation on the research being conducted at CMRR on modulation and coding for magnetic recording. The workshop was attended by approximately fifty persons (from IBM and various universities). The format of the workshop consisted of four one-hour invited talks (one being the talk by the CMRR group), and then a number of contributed shorter presentations.

The CMRR talk covered the following material:

Jack Wolf	Introduction to CMRR Combined Modulation/ECC Trellis Codes
Cathy French	Ternary Coding Scheme Utilizing (d,k) Codes and Write Equalization
Anthony Weathers	Peak Detection for Ternary Systems
Yinyi Lin	Sequential Decoding for both ECC and Modulation Codes
Lyle Fredrickson	A New Reed-Solomon Decoder Architecture

## New Publication: Research Abstracts

Technical papers resulting from CMRR research are listed in a new publication *CMRR Research Abstracts*. The first issue covered the period from CMRR's inception through 1986. Included are bibliographical details and an informative abstract for papers published in technical journals or conference proceedings. The unpublished research reports resulting from CMRR funded research projects are also included.

All papers are given a unique number and arrangement is by this number. An index by author's name is included. Published material is indicated by a PR prefix and the unpublished reports by a UP prefix. Copies of the complete text of any paper can be obtained by returning the order form included in the publication. The complete unpublished reports are available to members of sponsoring companies only.

A new edition covering all papers published during the year will be published in January of the following year.

## \$1.6 Million Grant from NSF

The National Science Foundation has awarded the University of California, San Diego a \$1.65 million grant for a three-year period to study the microscopic properties of magnetic materials. The research will be carried out at the Center for Magnetic Recording Research and represents the largest grant to CMRR in its four-year history. CMRR began funding the research about three years ago, and will provide significant funding during the next three years for a total contribution of about \$1.5 million. UCSD was chosen by the National Science Foundation as one of four new national Materials Research Groups which are sharing funding of \$7.4 million.

Ami Berkowitz, project director and holder of an endowed chair at CMRR, said the goal is to "understand more definitively the behavior of magnetic materials used in recording media so we can more readily accommodate higher density information storage."

Sheldon Schultz, UCSD professor of physics and one of the co-investigators on the project, explained that the researchers were concerned about the next generation of magnetic storage. "The grant allows us to pursue a research program to understand the interaction of ultra-fine magnetic particles," Schultz said. "I feel very confident that we will come up with a rather good explanation of how these ultra-fine magnetic particles interact in the next three years."

Other members of the research team are H. Neal Bertram of Electrical and Computer Engineering, who also holds an endowed chair at CMRR, Donald R. Fredkin of Physics, and Gareth Thomas of the Department of Science and Materials Engineering at UC Berkeley.

## Lecture Series Videotaped

Each month CMRR hosts the meeting of the San Diego Chapter of the Magnetics Society. Since 1986, the Center has been videotaping these lectures and also the weekly Tuesday afternoon CMRR seminar series. Other ad hoc seminars are also taped. All are recorded on standard VHS video-cassette tape and are available for loan to members of CMRR's sponsoring companies. The list of titles, together with an abstract, is published in the monthly *Bulletin* produced by the Information Center. Since this service was announced in the monthly *Bulletin*, there has been a heavy demand for the available tapes.

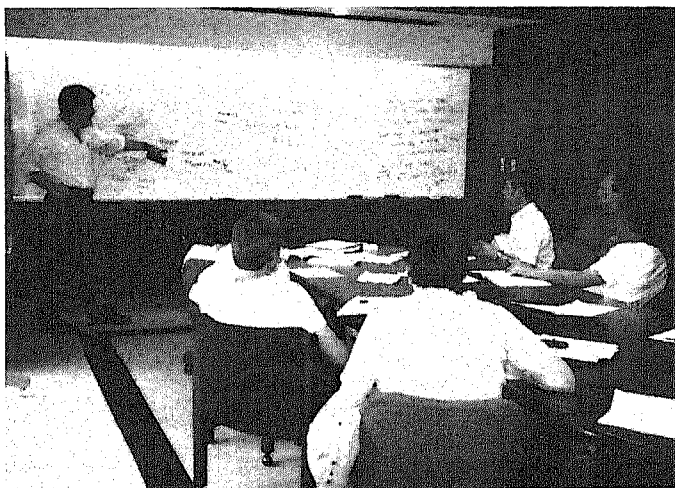
If you would like to see the list of available titles or would like to arrange a loan of a particular lecture, please contact:

Jan Neumann  
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University of California, San Diego  
La Jolla, CA 92093  
Tel: (619) 534-6199  
Fax: (619) 534-2720

## Laboratory Course on Techniques and Measurement Devices Used in Magnetic Recording

A two-week intensive laboratory course on fundamental measurements in magnetic recording was held at CMRR in June. The course was offered to industrial engineers through UCSD Extension and was taught by Professor Neal Bertram, assisted by Dr. Kuo-Nan Yang. Professor Bertram holds an endowed chair at CMRR. For sixteen years he was a member of the research department at Ampex Corporation. The course followed almost exactly the one-quarter UCSD course taught by Dr. Bertram as part of a year-long sequence on magnetic recording (ECE 210A-B-C). Sixteen scientists from companies including Apple Computer, Archive Corp., BASF, DOD, Hewlett Packard, IBM Corp., Kodak Corp., MPI, Nashua Corp., Pfizer Co., Polaroid Corp., and 3M attended. The course ran from 8:00 a.m. to 5:00 p.m. each day and included one to two hours of lectures daily on the theory of recording, with the remaining time spent on laboratory exercises and demonstrations.

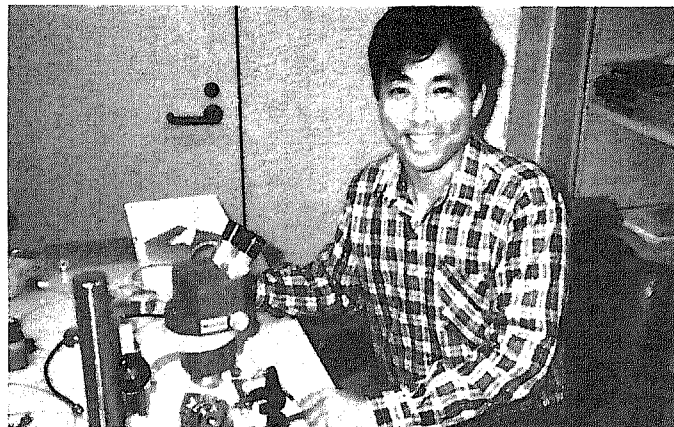
Three basic experiments were performed: head field measurements and Fourier transforms (2.5 days), head equivalent circuit modeling (2.5 days), and recording channel calibration and analysis (5 days). There were eight experimental stations (4 for heads and 4 for recording) so that students paired and changed experiments accordingly. The experiments are outlined below. In each of the experiments, the relationship between the measurements and basic physics of recording were emphasized. The philosophy of the course was for the student not only to become familiar with the fundamentals of the magnetic recording process, but to become proficient in the use of a spectrum analyzer, a microcomputer, an inductance bridge and a B-H loop. At the end of the course the students should be able to design heads as well as analyze inductance and efficiency. In addition they should be able to calibrate a recording channel and relate playback voltages to recorded magnetizations in the medium.



H. Neal Bertram with students

### COURSE DETAILS:

**Head Fields and Fourier Transforms**—In this experiment a variety of head configurations were analyzed using the technique of resistance paper plotting. The head shape was outlined with conductive paint and a DC voltage was placed across the head elements. The voltage at many points along a tape path was measured and entered into a computer. Software performed a simple derivative to give the longitudinal field as well as to take the Fourier transform. The latter gives the gap nulls as well as general shape losses. All attendees became familiar with the technique as well as verifying the basic gap and spacing loss formula by beginning with a simple ring head. Following that, various head structures such as a finite length head (thin film head), keepered probe and ring heads, and magnetoresistive heads were analyzed.



Kuo-Nan Yang

**Head Equivalent Circuit Modeling**—In this experiment the frequency response of head inductance and core permeability were measured. Equivalent circuit analysis was used to relate the complex permeability measurements of the core to the complex inductance of the head structure. The core saturation magnetization and coercivity were measured by calibrating a simple B-H loop. Attendees had a choice of ferrite or metal head materials. Eddy current and domain wall loss mechanisms were studied. A technique to determine the efficiency from inductance and permeability measurements was investigated.

**Recording Measurements**—Channel calibration and fundamental recording measurements were performed. The saturation magnetization of a tape was determined by recording saturation square waves and utilizing a solenoid for replay. The solenoid dimensions were used to determine, by Fourier analysis, the playback spectrum. Channel calibration was obtained by injecting voltage into the playhead and measuring the frequency response at each stage (which in an audio recorder are the head terminals, the integrator, the NAB equalization and the amplifier). Gap lengths and head efficiencies were measured utilizing recorded spectra. Attendees chose either AC bias (analogue) or unbiased (digital) recording to analyze recording spectra in terms of the recorded magnetization patterns and record process theory.

## Faculty Visit to Netherlands

On September 8, 1987 Jack Wolf participated in the Ph.D. final examination of J. W. M. Bergmans at the Technical University of Eindhoven, the Netherlands. Professor Wolf served as one of two "promoters" for the dissertation which was entitled "Partial Response Techniques and Robustness in Data Equalization." Dr. Bergmans, an employee of Philips Research Laboratory, has published a number of papers on magnetic recording and his thesis was a compilation of six of these papers. As part of his stay in Eindhoven, Professor Wolf visited the Philips Research Laboratory where he presented a seminar entitled "Research in Signal Processing for Magnetic Recording at CMRR." He also presented a seminar entitled "Modulation Codes and Applications in Magnetic Recording" to the Electrical Engineering Department at the Technical University of Eindhoven.

## CMRR Director Writes Textbook

John C. Mallinson, director of CMRR, has written a textbook, *The Foundations of Magnetic Recording*, published in November 1987 by Academic Press.

This textbook presents a comprehensive overview of the science and technology of magnetic recording from basic physics to system design considerations. The ten chapters cover: the physics of magnetism, magnetic measurements, recording media, recording heads, the writing processes, the reading processes, noise processes, audio and instrumentation recorders, video recorders and digital recorders. The book is aimed at the senior undergraduate or graduate level of study and should also be of particular interest to scientists, engineers and technicians working in the magnetic recording industry.

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## Calendar

**November 30–  
December 5, 1987** Materials Research Society, Boston, MA  
*For further info:* MRS, 9800 McKnight Rd.,  
Pittsburgh, PA 15237, (412) 367-3003

**December 1–3, 1987** Interactive '87, Brighton, England  
*For further info:* Interactive Video Assn.,  
0733/60535

**December 1–3, 1987** Optical Information Systems '87, New York, NY  
*For further info:* Conference Management Corp.,  
(203) 852-0500

**December 7–11, 1987** Video Expo, Orlando, FL  
*For further info:* Knowledge Industry Publications,  
Inc., (914) 328-9157

**January 10–15, 1988** O-E/LASE '88, Los Angeles, CA  
*For further info:* SPIE, (206) 676-3290

**February 16–18, 1988** International TOC Conference on Optical Memory  
Technology, London, England  
*For further info:* TOC, P.O. Box 14817, San Fran-  
cisco, CA 94116 (415) 681-3700

**February 21–26, 1988** Video Expo, San Francisco, CA  
*For further info:* Knowledge Industry Publications,  
Inc., (914) 328-9157

**February 29–  
March 4, 1988** CompCon Spring '88, San Francisco, CA

**March 1–3, 1988** 3rd International Conference on CD-ROM,  
Seattle, WA  
*For further info:* Microsoft Corp., Box 97017, Red-  
mond, WA 98083 (206) 882-8080

**March 21–24, 1988** 7th International Conference on Video, Audio &  
Data Recording, University of York, England  
*For further info:* Conference Secretariat, Institu-  
tion of Electronic and Radio Engineers, 99 Gower  
Street, London WC1E 6AZ

**July 11–15, 1988** 4th Joint MMM/Intermag Conference, Vancouver,  
British Columbia, Canada  
*For further info:* Courtesy Associates, 655 15th St.,  
NW, Suite 300, Washington, DC

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