UNIVERSITY OF MINNESOTA

SIGNALS

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

SPRING 2000

The Wonders of Wireless!

ECE Researchers Help Tune in Next Generation

In an infamous scene from the movie *The Graduate* Dustin Hoffman's character is offered a one-word tip — "Plastics!" — that supposedly will open the door to a successful future in business. If the script was written today, the tipster might well whisper: "Wireless Communications." Few areas of technology are likely to expand as rapidly as wireless communications.

Cell phones, once a status symbol, are nearly as commonplace as standard telephones. Soon, high speed, mobile wireless telecommunications will become the norm, opening the door to mobile wireless Internet access and cars with onboard computers with smart maps that identify nearby restaurants, gas stations, and emergency services. The so-called "Bluetooth" devices — appliances that communicate wirelessly with one another — will enable the average Joe or Jane to have a totally interactive house.

The University of Minnesota's Department of Electrical and Computer Engineering has a deep and accomplished contingent of wireless communications researchers. Included in this group are Professors Mohammed "Slim" Alouini, Rhonda Franklin Drayton, Georgios Giannakis, Anand Gopinath, Ramesh Harjani Mos Kaveh, Keshab Parhi, Ahmed Tewfik, and Nikos Sidiropoulos. In this issue of Signals, we're going to focus on the current research of Drayton, Giannakis, Harjani, and Parhi.

Rhonda Franklin Drayton

"The work we're doing may provide a vehicle for taking very well-understood high frequency design techniques and transferring them into a more affordable domain."

Rhonda Franklin Drayton: Affordable Wireless Solutions

"Unlike many other so-called technological revolutions, the push in wireless communications is being driven by consumerism," says Assistant Professor Rhonda Franklin Drayton. "When special agencies such as NASA or the Department of Defense were the driving forces behind technological advances, performance was of the utmost importance. Cost was secondary, at best. With consumerism at the helm, economics is now the driving force."

Wireless, continued on p. 3

INSIDE OUT

The 1999-2000 academic year marked the return of the University of Minnesota to the semester system. This change was an enormous undertaking, requiring countless hours of preparation by faculty and staff members. The main challenge was to provide a pedagogically sound curriculum and to make the transition as seamlessly as possible for students caught in the midst of the changeover. Fortunately, the transition was successful with minimal disruptions in the students' progress toward their degrees. Professor Larry Kinney, ECE associate department head, and Principal Student Personnel Worker Kathleen Propp deserve special recognition for their efforts in helping our undergraduate students work through the conversion of their programs from quarters to semesters.

The semester conversion also provided the department with an opportunity to examine and update its curriculum. For example, a number of our undergraduate core courses and laboratories were changed to provide a more integrated treatment of circuits and electronics. Exploratory laboratory exercises carried out individually by students are followed by team design projects in accord with the department's educational goals and vision.

This has also been a busy year related to the accreditation of the electrical engineering and computer engineering degree programs. During the fall semester, a team from the Accreditation Board for Engineering and Technology (ABET) visited us to review the recently established computer engineering program. Formal notification of the result of the review will be issued by ABET this summer. However, all indications are that the review was positive.

The Fall 1999 ABET visit was under the old ABET criteria. During the Fall Semester 2001 all engineering programs at the University of Minnesota's Twin Cities Campus will be reviewed by ABET under the new ABET criteria, commonly-known as Engineering Criteria 2000 (EC2000). EC2000 requires programs to establish educational program objectives and outcomes. Assessment instruments must also be determined to evaluate the outcomes and to provide ongoing feedback for the updating and improvement of the program. Involvement of constituencies is fundamental to the establishment of the objectives and assessment of the program. The faculty, in consultation with the department's Industrial Advisory Council, has established the objectives and outcomes for the EE and CompE programs.

We use formal surveys of our graduating seniors, selected alumni, and employers of our graduates as part of the assessment process. However, we also encourage and welcome additional feedback from everyone.

Two distinguished faculty members joined the ranks of emeritus professors during the past year. They are Professor Emeritus Mahmoud Riaz, a faculty member here since 1959, and Professor Emeritus Fredric Bailey, a faculty member here since 1964. Three new colleagues joined us this year. They are Professor Richard Kiehl, who came here from Stanford, Associate Professor Nikos Sidiropoulos, who previously taught at the University of Virginia and also holds a faculty position in the University's Digital Technology Center, and Assistant Professor Babak Ziaie, who completed a post-doctoral stint at the University of Michigan. Students and faculty at the University recognized several of our colleagues with awards for the excellence of their contributions in a number of areas. Professor Larry Kinney received the 1999 George Taylor Service Award and the 2000 HKN/ECE Teaching Award, Professor James Leger received the 2000 George Taylor Research Award, Professor Keshab Parhi became a McKnight Distinguished Professor, and Professor Anand Gopinath garnered the IT Student Board ECE Teaching Award.

In closing, I wish to once again take this opportunity to thank our alumni and friends of ECE for generously supporting our students and programs. I encourage you to visit our brand new web site (www.ece.umn.edu) that was designed and developed by one of our Ph.D. students, Keesook Han. We'd appreciate hearing from you.

With my best wishes,
M. Kaveh
Professor and Head

SIGNALS

M. Kaveh
Department Head

L .L. Kinney
Associate Head & Director of Undergraduate Studies

B. Wollenberg
Director of EE Graduate Studies

G. Sobelman
Director of CompE Graduate Studies

Signals is an annual newsletter published by the University of Minnesota Department of Electrical and Computer Engineering. We welcome letters, news about electrical and computer engineering alumni, and story ideas from all readers. Correspondence should be addressed to: *Signals*, Department of Electrical and Computer Engineering, University of Minnesota, 200 Union Street S.E., Minneapolis, MN 55455. The ECE web page can be found at: www.ece.umn.edu

The University of Minnesota is an equal opportunity employer and educator.

PRODUCTION

Chuck Benda, *Managing Editor*
Dawn Mathers, *Designer*
John Marchetti, *Photographer*

Wireless, continued from p. 1

With cost being such a critical factor for consumer products, researchers like Drayton are searching for ways to transfer cutting-edge high frequency technology (that was pioneered in relatively expensive materials) into more affordable materials.

"The cheapest materials aren't necessarily the best substrate—or, in some cases, even acceptable — when it comes to transferring existing high frequency techniques into rf solutions," explains Drayton, whose niche is high-frequency/microwave wireless communications. "The work we're doing may provide a vehicle for taking very well-understood high frequency design techniques and transferring them into a more affordable domain."

In this case, the domain is silicon. Drayton is pursuing "affordable" solutions in two critical areas: packaging and interconnects. In packaging, she has done extensive work using silicon micro-machining techniques to shape the electrical packaging in ways that optimize the electrical characteristics for high performance. Silicon is a high-loss material. When fabricating high performance circuits in silicon, losses such as electrical radiation create all sorts of problems as the energy from one circuit "couples over" into another.

While working on her Ph.D. thesis, Drayton used micromachining to shape packaging and mitigate radiation-related problems in the electrical domain. She is now exploring using the same concepts in the optical domain.

"Ideally, we hope to use micromachining technologies to combine the electrical and optical domains on a single microbench," she says. "If, at the same time, we can effectively integrate the interconnects, we can develop a number of design efficiencies and greatly simplify the fabrication process."

Drayton's research group has successfully fabricated simple interconnects (coplanar wave guides) on synthesized substrates. "We use micromachining technology to shape the substrate locally, removing material in the pattern of the circuit," she says. "The shape of the package can alter the electrical characteristics of silicon, opening the door to fabricating high-performance devices. We've been able to shape the substrate in such a way that it reduces the radiation, so that it doesn't couple over to the next circuit."

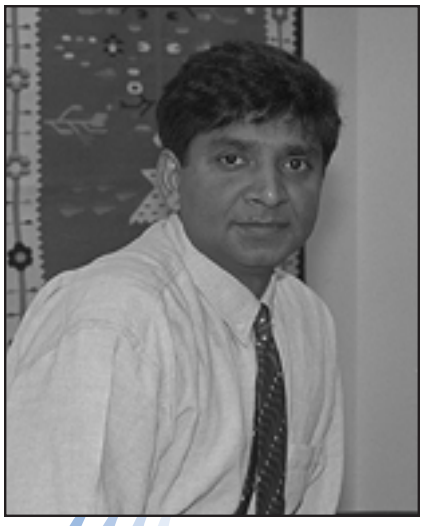
The research group is currently exploring the use of oxidized porous silicon as a high frequency material with microstrip lines. But first, they have some obstacles to overcome in materials development and characterization.

"To date, these kinds of high frequency [microwave and millimeter-wave] circuits have only been done in high-resistivity silicon," says Drayton. "Our goal is to develop good high-frequency circuits in a low resistivity silicon environment — which is where all the CMOS processing is done. That would reduce and, in some cases, eliminate out-boarding and offer direct integration of both the processing circuitry and the high-frequency circuitry onto a single chip. And that means cost would go way down."

Ramesh Harjani: The Magic of Bluetooth

The world of high-technology is rife with flavor-of-the-month innovations that, one day, are predicted to revolutionize our lifestyles, and the next, conveniently forgotten. In the midst of this fast-changing landscape, however, Bluetooth seems to be showing some legs. Bluetooth is the colorful descriptor of a wide-range of wireless communications applications that will allow appliances of every sort—from palm pilots, to refrigerators, to stereos—to communicate with one another and thereby (supposedly) improve the quality of our lives. If the amount of money some of the world's leading high-tech companies have invested in Bluetooth technology is any indication, your coffee maker may soon be talking to your cell phone whether you like it or not.

"Bluetooth is terribly complicated and challenging for the people who are trying to make it work," says Professor Ramesh Harjani. "If it is to succeed, it will have to be very low-cost and simple for the users."



Ramesh Harjani

"Bluetooth is terribly complicated and challenging for the people who are trying to make it work. If it is to succeed, it will have to be very low-cost and simple for the users."

Harjani's research group is among those trying to make Bluetooth work. Currently, they're working on more than half-a-dozen Bluetooth research projects. They've made some progress on each. In three areas, however, their success has been particularly noteworthy: phase locked loops (PLLs), low-noise amplifiers LNAs), and copper interconnects.

In theory, one would like to be able to send a signal that is exactly at a single frequency so that there would be little noise or interference from other signals or to other signal channels. In reality, it is impossible to generate a perfectly clean single tone. However, one of the best techniques currently available to generate low phase noise signals is with the help of PLLs.

"One of the most difficult things to design into wireless circuits is the capacity to produce an incredibly accu-

Wireless, continued from p. 3

rate signal with low phase noise," says Harjani. "Until now, the only way it's been accomplished is to use LC-tank oscillators in PLLs. LC-tank oscillators have limited tuning range, cannot accommodate large process variations, occupy large silicon area, and are more difficult to design than ring oscillators. We've been able to achieve comparable levels of phase noise with a ring oscillator, which allows the system to be designed much more easily. This represents a real breakthrough."

Another challenge in designing wireless systems is creating systems that can detect extremely small signals yet still handle big signals. In order to do so, a high degree of linearity must be built into the amplifiers. Current cell phones rely on gallium arsenide LNAs to accommodate the linearity (or IIP3) requirements. "We've shown in theory and through simulation that we can create the desired LNAs in CMOS," says Harjani. "Now, we've sent our chip out for fabrication and are awaiting measurement results."

Copper has a number of desirable characteristics for use in wireless circuit design. Members of Harjani's group have been incorporating copper passive components into wireless communications chips. Recently, a wireless circuit design they developed using a 0.18u copper CMOS process was selected as one of the five best nationally in a competition sponsored by Semiconductor Research Corporation. "Forty-three teams from 34 different universities entered the competition," Harjani says. "It was especially satisfying to be recognized."

"Although no one has produced Bluetooth systems yet, many, many companies are targeting low cost, single chip solutions for Bluetooth," says Harjani. "They are supposed to begin deploying them later this year and some forecasters predict that there will be between 200 million and 600 million Bluetooth systems in operation by 2003."

Whether you think you need it or not, it looks like Bluetooth is on its way.

Georgios Giannakis: 4th Generation Wireless

"Compared to multimedia, the challenges of wireless voice communications are easy to deal with," says Professor Georgios Giannakis. "One reason is that when you miss part of what a person is saying you can generally fill in the gaps. But when you're transmitting multimedia and you lose some of the data that represents an algorithm, you've pretty much lost everything."

Giannakis is the PI on a large, interdisciplinary research project addressing these and other challenges to 4th generation wireless communications. (Co-PIs include ECE faculty members Mohamed "Slim" Alouini, Department Head Mos Kaveh, John Kieffer, and Ahmed Tewfik, and, Z. L. Zhang from Computer Science and Engineering) The project targets mitigation of channel impairments in the propagation medium, including multipath propagation, multiuser interference, and time-selective fading, as well power consumption.

"With mobile wireless, the propagation medium is in constant flux, so you need to develop 'smart' algorithms that track the propagation medium and adjust accordingly," says Giannakis. "We're addressing these issues on both the physical level and the networking level using a new modality for channel access."

To date, the most common methods of allowing multiple users to access channels are time division multiple access (TDMA), frequency division multiple access (FDMA), and code division multiple access (CDMA).

"We have combined elements of each of these modalities in what we call generalized multicarrier CDMA," says Giannakis. "We're developing new algorithms, as well as new physical designs for transmitters and receivers, for example, that work with our algorithms. This allows us to route information and transmit information optimally. We're also making use of multiple antennas at the transmitter end. We can then combine the signals at the receiver, which allows us to make diversity gains."

Georgios Giannakis

"With mobile wireless, the propagation medium is in constant flux, so you need to develop 'smart' algorithms that track the propagation medium and adjust accordingly,"

To date, the research group has developed algorithms that can handle multiple propagation, multiuser interference, and fading. They've been tested in simulation and performed admirably. Giannakis says they should be able to build a system that will reduce errors by two to three orders of magnitude, increase bandwidth by 30 to 40 percent, and increase rates of transmission by as much as 30 percent.

"This summer, we'll move to a proof of concept," he says. "We're building a test bed and will begin transmitting from one side of the building to the other. Then, we'll move outside, and then to a mobile setup that mimics the reality of functional wireless communications."

They'll be looking at how well their system performs in terms of power consumption, bandwidth efficiency, probability of error, and transmission rates. Initially, they hope to be able to achieve a transmission rate of 16 megabits per second, with high levels of accuracy and reasonable levels of power consumption.

"There are many challenges yet to be solved before we achieve totally mobile wireless," says Giannakis. "The faster you move the more problems you encounter. The ultimate goal is to send and receive up to 100 megabits of data per second accurately while traveling at automotive vehicle speeds."

Although that is a dramatic increase over current capabilities, Giannakis' sees it as a goal that can be reached in three to five years.

Keshab Parhi: Building Blocks for Success

One of the keys to practical and versatile 4th generation wireless lies in the design of new very-large-scale integrated circuits (VLSI) for digital signal processing (DSP). Simply stated, the goal is to develop smaller, faster DSP chips that require less power. Keshab Parhi, the ECE Department's Edgar F. Johnson Professor has been approaching that goal with a three-pronged attack.

"My research group has focused on optimizing VLSI architectures and algorithms, as well as developing better computer-aided design tools," says Parhi. "We've been working with both pipelined and parallel processing techniques."

For both architectures and algorithms, one might say that Parhi's research group has become successful by designing better building blocks. In the case of architectures, according to Parhi, it's a matter of determining what kind of building blocks will work best—which filter structure, for example—and in what sorts of layouts. When it comes to making better algorithms, they have focused on optimizing the arithmetic building blocks of the algorithms — the adders, dividers, and multipliers—so that they offer a high level of throughput with low levels of power consumption.

"By the end of this year or the first quarter of next year we hope to be able to demonstrate .13 micron technology that operates efficiently at 1.2 volts of power," says Parhi. "That means we have to overcome the inherent increase in propagation delay that comes with a reduction in supply voltage by reducing the latency, or critical path."

The design tool that Parhi's group developed is called HEAT. It is a two-level, hierarchical tool that allows them to estimate power consumption in various data paths. VLSI DSP chips are incredibly complex. Designing new DSP chips is extremely time-consuming. By allowing them to estimate power consumption rapidly, HEAT streamlines the design process.

Block by block, Parhi's research group is putting together little breakthroughs that amount to big progress toward 4th generation wireless. Parhi noted four recent advances his group has made:

- development of a technique for parallelizing Huffman codes. Huffman codes, which are used to provide "loss-less" data compression, had been notoriously difficult to parallelize because the code words lacked definitive boundaries.
- a significant reduction in the amount of power required for turbo-coding. Turbo coding is a class of "error-control" coding developed about six years ago. It is an iterative process, that had required eight iterations. Parhi's group developed a way to accomplish the same thing in two to three iterations, which leads to a substantial reduction in power consumption.
- the design of a correlator that uses 49 percent less power. "Basically, we came up with a smart design at the 'arithmetic' level that allows us to implement the correlator in a different way.
- the design of a coordinated digital integrated circuit (CORDIC) implementor (another building block that has multichannel and beam forming applications) that is fast and very low power.

Keshab Parhi

"When it comes to 4th generation wireless, and the vast amounts of data that must be transmitted, the work that is being done throughout this department is absolutely essential."

"The research work that is being done, not only by our group, but throughout the ECE department, has implications for all forms of wireless communications," says Parhi. "For current generation cell phones, it may simply mean the batteries last a little longer. When it comes to 4th generation wireless, however, and the vast amounts of data that must be transmitted, the work that is being done throughout this department is absolutely essential."

Center for Electric Energy Funding Renewed and Increased

The ECE department's Center for Electric Energy recently received a very critical piece of funding in the form of a renewed grant from seven regional power companies. The grant includes a 17 percent increase that will be phased in over the three-year term of the renewal.

"This core-level funding is extremely critical to the health and vitality of the Center for Electric Energy," says Professor Bruce Wollenberg, who serves as the center's director. "It provide us with direct support for students, equipment purchases, and other needs; as well as matching funds for other grants. Plus, it helps bridge the gap between other research contracts."

The companies providing the grant monies to the Center, which was founded in the early 1980s, are: Northern States Power Company, Otter Tail Power Company, Minnesota Power Company, Great River Energy, Alliant Energy, Dairyland Power Cooperative, and Southern Minnesota Municipal Power Authority.

"Even though we're small, we're recognized as one of the top programs in the country," says Wollenberg, who noted that the Center plays a critical role by helping the ECE department offer a diverse educational program and by serving the needs of the power industry.

"I think it's pretty unusual in these times of deregulation for a bunch of companies that are now essentially competitors to come together to fund the center," adds ECE Professor Ned Mohan, who also works within the Center. "But the work we do is crucial to these companies, both in terms of the students we train and the research we conduct."

The success of a recent research project undertaken through the Center will give power companies better tools to work with in times of deregulation, according to Wollenberg.

"Anytime power is transmitted across lines, there are what are known as reactive losses, essentially from the wire heating up," he says. "As power is sold from one company to another, and then transmitted from grid to grid, these losses add up. Companies want to know how to accurately allocate the losses to each participating company. We developed the algorithm to do so accurately and are working with a commercial software developer to produce a commercial product to accurately calculate and assign those losses."

Mohan's research group recently developed an extremely efficient battery charging circuit that also offers very high power density coupled with very low electromagnetic interference. In addition to battery charging, the circuit may well have significant applications in digital computers, communications, and automobiles, according to Mohan.

"Our relationship with these companies is really win/win for everyone involved," says Wollenberg. "Each summer we offer seminars that provide their engineers with the continuing education credits they need. Sometimes we provide them with free consulting services. In turn, they do things like advising on student projects and providing us with support letters for grant proposals."

Campbell Named Director of MTL

Professor Stephen Campbell was appointed director of the Microtechnology Laboratory (MTL), effective September 1. MTL supports education, collaboration, and faculty and industry research in microelectronics and microfabrication.

"This is a tremendous opportunity for me, because it gives me an insider's look at all of the cutting-edge research going on in the lab," says Campbell, who replaces Professor Dennis Polla as head of MTL. "We've got researchers from across a wide spectrum of disciplines—everything from electrical and computer engineering to biomedical engineering—doing some very exciting things in here."

Research projects supported by MTL include what might be considered traditional microelectronics and microfabrication efforts, such as materials development and characterization and semiconductor device fabrication. Other MTL research is more wide-ranging, however, and includes work in developing surgical microinstruments and bioanalytical microsystems, such as single-chip mass spectrometers or DNA extractors.

The lab itself is outfitted with state-of-the-art equipment and offers researchers access to 3,000 square feet of class 10 clean room space, and 2,700 square feet of class 100 space, as well as 3,000 square feet of space for technical support. Recent equipment acquisitions include a new evaporator for thin film deposition and a new track system for photo lithography processes. Both internal University users and external users are charged a fee (external users pay at a higher rate) to access MTL facilities.

"The lab is well positioned for continued success," says Campbell, who also uses MTL for his research. "We have no major needs in terms of capital equipment. The key for us to continue to attract researchers to utilize this wonderful facility."

New Course Brings CLA, ECE Students Together

A new course offered during fall semester, *ECE 1701: Energy, Environment, & Society*, attracted 40 percent of its enrollment from the University's College of Liberal Arts, which is exactly the sort of broad-ranging appeal that Adjunct Professor Paul Imbertson, the instructor and course developer, was hoping for.

"Each of the topics listed in the course title are intertwined with one another on a number of different levels and impact greatly on our lives," says Imbertson. "And yet, oftentimes courses that address these issues are designed in a way that excludes many groups of students. We wanted a course that could appeal to the full spectrum of students and still deal with the course matter in a meaningful way."

The course, which will be offered again next fall, attracted an interesting mix of students: a 60/40 split between IT and CLA students; 50/50 freshmen vs. upperclassmen. This limited study methods and forced Imbertson to resort to the use of analogies and metaphors to convey a variety of technical concepts to his students.

"Although the non-engineering students didn't have the mathematical and theoretical tools to work with some of these concepts the way engineers typically do, by the end of the course they understood the material in a way they never did before," he says. "The engineering students also gained a deeper understanding by approaching the material from a different perspective. That kind of understanding is critical if they are to make responsible decisions regarding issues such as such as energy shortages, rising oil prices, and global warming. And maybe by bringing non-engineers into such a course we might just attract someone out there with great talent who's an electrical engineer at heart but just doesn't know it yet."

Semester Conversion Nearly Seamless

The beginning of the 1999-00 school year marked the first session under the semester system for students at the University of Minnesota and, according to ECE Professor Larry L. Kinney, the department's director of undergraduate studies, the transition went about as smoothly as could be expected.

"Perhaps the best measure of success is how easy it was for the students to figure out what to do under the semester system, as compared to the old quarter system," says Kinney. "I'm sure some of our students were frustrated by the changes, but all in all, the changeover went well."

Faculty members began preparing for the change almost two years ago. The major changes to the curriculum included:

- revamping the beginning circuits course and adding to it some of the electronics material that used to be done in the third year,
- expanding the senior design course to the full semester, and
- providing for more freedom in choosing senior electives.

Under the new system, students must complete 126 semester credits to earn a bachelor's degree, which is marginally down from the prior requirements. All new students automatically begin under the semester system. Returning students, who have until 2006 to complete their degree requirements, will take the new semester courses, but their requirements are based on the old quarter system.

"This has been a very positive experience for the department, despite the unavoidable frustrations," says Kinney. "Because we were forced to review and adapt the entire curriculum, a number of courses improved substantially. Plus, it allowed us to do a better job of integrating the computer engineering classes into our overall curriculum. The entire faculty was involved in the process, and they did an excellent job."

Riaz Retires, Remembers His "Day" in the Sun

For Professor Emeritus Mahmoud Riaz, who turned 75 in February, the decision to retire before the start of the 1999-00 school year wasn't a difficult one to make. "It was about time," says Riaz, with a wry smile. "I decided I would begin the new millennium by not having to be here at 8:00 a.m. and not having to go through the semester converstion."

Riaz has had a long and illustrious career working in electric energy conversion systems and their control, particularly solar energy and electric power systems. An Egyptian national of Turkish and Albanian descent, he was born in Paris in 1925 and grew up living in Switzerland, France, Morocco, and Egypt. He earned a bachelor's degree in law in 1944 through an extension of the University of Paris and a bachelor's degree in electrical engineering from the University of Cairo in 1946 before coming to the U.S. and earning two more electrical engineering degrees—a master's degree from Rennselaer Polytechnic Institute in 1947 and a doctor of science degree from Massachusetts Institute of Technology (MIT) in 1955.

From 1947 to 1959, Riaz worked at MIT as a teaching and research assistant, an instructor, and an assistant professor. In 1959, he joined the faculty of the electrical engineering department as an associate professor. During his career at the University of Minnesota, Riaz served as Director of the Coop Program, as well as Director of Undergraduate Studies. At the same time, he worked as a consultant for numerous private and government entities. It is, however, his "solar days" he remembers most fondly.

"In the early 70s, solar energy had become a very hot topic of research and I became involved through a research project that used parabolic mirrors to concentrate the solar energy on a boiler perched atop a tower," says Riaz. "That marked the beginning of the most interesting decade of my career."

Riaz became one of the first "experts" on solar energy. He collaborated on a research project that examined the potential for storing solar energy in large rock beds. In 1976, he was an invited participant in the Arab Solar Energy Congress. In 1978, the Department of Energy sent him as its representative to the International Solar Energy Congress in New Delhi, India. A year later, the Chinese government invited Riaz to lecture on solar energy and electric power systems at Tianjin University, making him one of the first U.S. scientists to travel to China following reestablishment of formal relations between the two countries.

"That period of my career was exhilarating," says Riaz.

When the interest in solar power faded with the falling price of fossil fuels, Riaz shifted his fcous back to power drives and electric machines. Although he plans to continue during his retirement, it will on a more casual basis. He and his wife hope to travel more, exploring the Caribbean, among other destinations. "I stood in front of a blackboard for 52 years," he says. "I think that's about enough, don't you?"

In the "shorthand" of his profession, **Associate Professor Nikolaos Sidiropoulos** researches signal processing and communications, focusing on linear and multi-linear algebra, multi-way analysis, non-parametric regression theory and algorithms, and optimization. If you listen to him describe his research in his own words, however, Sidiropoulos' passion for the work that he does emerges from the shadows of the technical language.

"Several aspects of wireless voice and data communications can be readily understood in the framework of three- and higher-dimensional matrix analysis," says Sidiropoulos, who joined the ECE faculty in January. "There is some very beautiful mathematical theory that applies directly to these matrices."

That "beautiful theory" helps Sidiropoulos construct and analyze multi-dimensional data pertaining to wireless communications. Working primarily at the mathematical end of things—modeling, analyzing, constructing algorithms—Sidiropoulos is currently focusing his efforts on two main areas of research: (1) multi-way analysis techniques as they pertain to common wireless communications problems such as separating and distinguishing user transmissions and detecting the direction from which they are

Nikolaos Sidiropoulos

arising, and (2) the resolution of problems that arise when data packets collide with one another. Sidiropoulos offered an example of some recent progress he has made in this second area.

"In current random access systems, we send out data packets, hoping they won't collide," he says. "When they do, however, the data is lost and the packets have to be resent. By forcing the packets to collide again, however, you can recover the original data intact [using algorithms Sidiropoulos devised], while at the same time realizing a gain in overall utilization of the system."

A native of Greece, Sidiropoulos came to the U.S. to study electrical engineering at the University of Maryland, where he earned his master's and Ph.D. degrees in 1990 and 1992, respectively. He returned to Greece to serve a two year stint in the army before joining the research faculty at the University of Maryland in 1994. After three years, he moved to the University of Virginia where he was an assistant professor for three years.

"The University of Minnesota is good fit for me," he says, "The ECE department has a very strong group of researchers in signal processing, and I'm looking forward to working in that environment and collaborating with my new colleagues."

As an Iranian born in Vienna, Austria, and educated at the University of Tehran (B.S. 1986, EE) and the University of Michigan (M.S. 1992, EE; Ph.D. 1994, EE), **Assistant Professor Babak Ziaie** might truly be said to be a citizen of the world. But, given his research interests, there are few (if any) other places on this planet that fit him so well as the University of Minnesota.

Faculty Update, continued next page

Bailey to Explore Music, Languages in Retirement

Professor Emeritus Fredric N. Bailey, 68, isn't the least bit worried about what he will do to occupy his time, now that he has retired. In fact, from the sound of things, he may be busier than ever.

"Having time to do some of the things I've always wanted to do is the best part of retirement," says Bailey. "Throughout my life I've enjoyed music, and now I'm getting a chance to explore it more thoroughly."

A native of Ohio, Bailey earned his bachelor's degree in electrical engineering from Purdue University in 1953. He entered the U.S. Navy Pilot Training Program upon graduation, and spent a little more than four years in active duty, and then 17 years as a pilot in the Naval Reserve. During this time he flew everything from fixed-wing aircraft to helicopters to blimps. He retired with the rank of Captain in 1975.

After his active duty in the Navy, Bailey resumed his electrical engineering education earning both master's (1960) and Ph.D. (1964) degrees from the University of Michigan. When he began looking for a faculty position, the University of Minnesota seemed a natural fit.

"They had a good reputation so I made a visit to campus," he says. "I immediately like the area, and there was a very strong group of people forming a control sciences group in the Institute of Technology at that time."

Bailey fit right in. Control systems, specifically the area known as stability theory, was Bailey's cup of tea. He accepted a joint appointment in electrical engineering and the Center for Control Sciences and Dynamical Systems and became an early researcher in applications for digital computers in control systems. Baily also began to explore robust control. He developed a number of new courses in digital signal processing and digital control systems, as well as one of the first undergraduate digital control laboratories in the country. He published numerous articles on control theory, control system design, and signal processing and co-authored a book on hierarchical control systems theory.

Although he has decided to forgo his research in retirement, these days Bailey is using the digital computer to explore his hobbies. "There are a number of software tools that can be used to take standard arrangements and adapt the music for different uses," he explains. "I've been experimenting with some new arrangements for vocal groups, guitar, clarinet, and saxophone."

Bailey is a member of an a capella vocal quartet and also plays guitar, clarinet, and saxophone. He also enjoys learning languages, especially Spanish and German. With plans to travel to Germany soon, he's been brushing up on his language skills.

"I've always enjoyed these pursuits, but never have had the time to explore them fully," he says. "Now's my time for some new challenges."

Babak Ziaie

"The University's strength in biomedical engineering research and applications, as well as it's medical school—coupled with the proximity of Minnesota's Medical Alley, made this one of the best places I could be," says Ziaie, who joined the Electrical and Computer Engineering Department's faculty in October.

Ziaie's research interests are centered around solid-state sensors and actuators, and miro-machining technologies for biomedical applications. In particular, his work focuses on diagnostic, therapeutic, and rehabilitative microsystems such as implantable drug delivery systems and neural prosthetic devices. Prior to coming to Minnesota, Ziaie did postdoctoral work and research at the University of Michigan and the University of Alabama.

Currently, Ziaie is collaborating with researchers from the Mayo Clinic to develop the means to wirelessly and continuously monitor eye pressure in glaucoma patients. The plan is to develop an implantable microchip that includes both a pressure sensor and transmitter. The microsystem would transmit data to a small receiver on the patient's eyeglasses.

"No one has ever been able to monitor the eye pressure continually, over an extended period of time," says Ziaie. "There are many obstacles to overcome: the design of the sensor, the electronic readout, the transducers, and other circuits. I'm currently doing some tests with the surgeon who's collaborating on the project. This is a very exciting project. We hope to be able to monitor eye pressure continuously for a one-year period, which should really help physicians better understand and treat glaucoma."

The research work of **Professor Rick Kiehl** is so revolutionary, it might well be described as lying somewhere beyond the cutting edge. Although his work is related to the fabrication of traditional microelectronic devices, he's attempting to meld traditional microelectronics methods with biotechnology. The result is something that seems straight out of the pages of a Star Trek script.

"As microelectronics devices get smaller and smaller, we're moving into the scale of molecules and even atoms," says Kiehl, who joined the ECE department last spring. "At that scale, current lithographic processes no longer work. We're trying to use DNA as a scaffolding for self-assembling devices based on principles very different from those in transistors."

Rather than the lengthy strands of naturally occurring DNA, Kiehl works with short strands of synthesized DNA, which assemble themselves into two-dimensional structures resembling corduroy fabric. He's fabricating simple test structures such as gold nano-particle arrays and nano-wires, but is not far away from being able to fabricate test devices for a "proof of concept."

Kiehl, who grew up in Ohio and Pennsylvania, earned his Ph.D. degree in electrical engineering from Purdue University. Prior to coming to Minnesota, he worked for Sandia National Laboratories, Bell Laboratories, IBM's T. J. Watson Research Center, and Fujitsu Laboratories (Japan); and on the electrical engineering faculty at Stanford University.

Rick Kiehl

In addition to the strength of the electrical and computer engineering department, the University's strong chemical engineering and biochemistry programs attraced Kiehl to Minnesota. "Using basic chemistry and biochemistry to assemble electronic devices seems to be the way of the future," he explains.

This new generation of devices will hardly resemble current semiconductor devices. Furthermore, they will be based on new, and very different, physical methods.

"The densities of these devices are several orders of magnitude beyond the limits of conventional technology," Kiehl says. "More importantly, however, these devices may lead to entirely new ways of processing information by using circuit architectures that are reminiscent of those naturally occurring in the brain."

ALUMNI NEWS

1949

Everett H. Dale of Edina is currently president of Dale and Associates, a Minneapolis consulting firm specializing in manufacturing and service excellence. He is vice president of the Association for Manufacturing Excellence, a Fellow of the American Society for Quality, and an examiner for the Malcolm Baldridge National Quality Award. Dale, who has remained actively involved with the University of Minnesota throughout his career, recently served as Chairman of the committee for the 50th Reunion of the Institute of Technology Class of '49.

Francis J. Vojta and Margaret L. Vojta have established the Vojta Family Scholarship Fund.

1990

Jack J. Zhu (M.S.) has been recognized in *Who's Who Worldwide* for his contributions in developing a thin film machine for hard disks with one micro-inch accuracy, which dramatically increased memory capacity of such devices. Zhu, who as a master's student under Professor E. B. Lee, is also recognized in the 1998-99 edition of *American Men and Women in Science*, and the 2000 edition of *International Who's Who*. Zhu currently lives in Fort Wayne, Indiana

In Memory

Sharon Y. Pierre, who earned her bachelor's degree from the ECE department in 1991, died in Laramie, Wyoming on July 18, 1999. She was married to John W. Pierre (M.S. 1989, Ph.D. 1991), who is currently an associate professor at the University of Wyoming.

IN BRIEF

Professor Keshab Parhi received a University of Minnesota Distinguished McKnight Professorship.

Professor James Leger received the IT George Taylor Research Award.

Professor Anand Gopinath received the IT Student Board Teaching Award for electrical and computer engineering.

Professor Larry Kinney received the HKN/ECE Department Teaching Award.

Professor Ramesh Harjani and his graduate students were named one of the five best teams nationally to respond to the Copper IC Design Challenge sponsored by the Semiconductor Research Corporation.

Professors Vernon Albertson, Mos Kaveh, Ahmed Tewfik, and **Bruce Wollenberg** received the IEEE Third Millennium medals for outstanding contributions to their respective areas of activity.

Professor E.B. Lee was elected a foreign member of the Polish Academy of Sciences.

NEWS ABOUT YOU

Accepted a new job? Moved? Won an award? The Department of Electrical and Computer Engineering—and your former classmates—want to know. Please fill out this form and send it (along with relevant newspaper articles or press releases) to Signals, Department of Electrical and Computer Engineering, University of Minnesota, 200 Union Street S.E., Minneapolis, MN 55455. We'll pass the news along in an upcoming issue.

NAME _____ CLASS YEAR(S)/DEGREE(S) _____

ADDRESS _____ _____ _____ _____
STREET CITY STATE ZIP

TELEPHONE (____) _____ (____) _____
HOME WORK

NEWS _____

1999-2000

SCHOLARSHIPS

Chauncey L. Greene Memorial
Jay W. Axelrod
Laura Bohlman
Lance Schlimgen
Justin Tung-junyatham

Dora A. Hyverinen Scholarship
Elias Mulugeta Ayana
Kai-Chuan Chang

Hartig Fund
Rizwan Z. Ali
Shu-Ting Hsu
Wing Chuen Lau
Furqan Nanji

Kappa Eta Kappa
Matthew Paul Anderson
Alan Clark Fruland

Roger M. Nordby
Ryan M. Albu
Andrew Barry
Todd Andrew Begalke
Michael A. Erdmann
Ayres Fan
Benjamin Froemming
Andrew David Josephson
Melissa Faith Labeck
Brent R. Nelson
Andrew Niles Seelke
Jason Skoglund
Maximilian A. Smirnoff
Benjamin J. Winstead

Oscar A. Schott
Craig A. Hanson
Ahmed Khaleel
Thomas Martin Kleinschmit
Randy Lawrence Meyer
Hung Nguyen
Steve Lee Zellinger

Boeing
Karen Ho

Rosemount Engineering
Benjamin Winstead

FELLOWSHIPS

Fulbright Grant
Pornchai Phukpattaranont

IBM Fellowship
Travis Oenning

SRC Fellowship
Noel Hoilien

Department Fellowship
Brian Davidson
James Koeppe
Runhe Zhang

Graduate School Fellowship
David Sklenicka
Heather Orser
Ann Gabrys
Ross Schermer
Michael Shannon

National Science Foundation Fellowship
Rebecca Peterson

RECENT GIFTS

We would like to thank the following companies for their support during the past academic year.

Advanced Research Corporation
AlliedSignal Foundation Inc.
Dupont Corporation
Exxon
Ford Motor Co.
Guidant
Intel
IBM
Lucent
Medwave, Inc.
Minnesota Mining & Manufacturing
National Storage Industry Consortium
Northern States Power Company
NZ Applied Technologies
Rogers Corporation
Rosemount Engineering Inc.
The Schott Foundation
Seagate Technology
Sematech
Semiconductor Research Corporation
SemiCube, Inc.
SONY
StorageTek
Sun Microsystems
Texas Instruments

Electrical and Computer Engineering
University of Minnesota
200 Union Street S.E.
Minneapolis, MN 55455

ADDRESS CORRECTION REQUESTED

Nonprofit Org.
U.S. Postage
PAID
Minneapolis, MN
Permit No. 155