CAREERS

Not Your Mother's Mammography

In Susan Hagness' search for a better way to detect breast cancer, she gets her students involved, too

BY LAUREL M. SHEPPARD
Contributing Editor

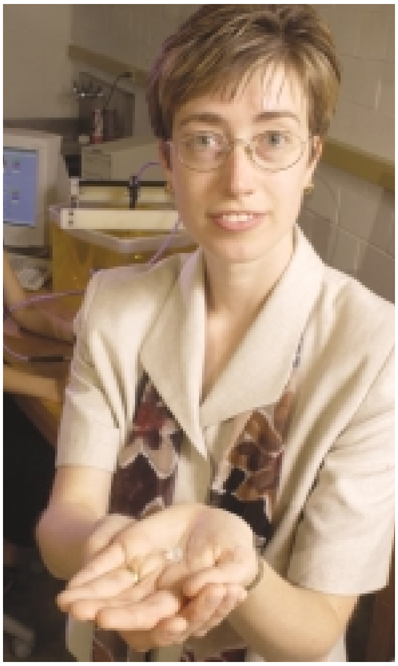
With over 200 000 new cases reported last year, breast cancer accounts for nearly one of every three cancers diagnosed in U.S. women. While great strides have been made in early detection, the conventional method of mammography is not failproof: it has trouble imaging dense tissue, it may show suspicious areas where no malignancy exists, and radiologists interpreting the images can miss up to 15 percent of cancers. It's also uncomfortable, requiring each breast to be compressed between plastic plates, which can lead to bruising.

Susan Hagness wants to change all that. An assistant professor of electrical engineering at the University of Wisconsin-Madison, she is pioneering a novel detection technique that uses ultrawideband microwaves to image even the tiniest malignant tumors in the breast. Breast tumors and normal tissue show much more contrast at microwave frequencies than at the X-ray frequencies used for mammograms. Microwaves are also nonionizing, and the technique requires no breast compression.

"In my mind, breast cancer detection is one of the most important and most challenging engineering problems," Hagness says. "It's exciting to be working on something that has so much potential for saving women's lives."

A better way

The approach that Hagness and her group are developing relies on algorithms originally developed for radar signal processing. In the procedure, a woman's breast is surrounded by an antenna array, and each antenna in turn transmits a low-power microwave pulse into the breast and collects the backscattered signal. Just as in regular radar, the arrival times and amplitudes of backscattered signals across the array are used to locate malignant lesions, based on the large contrast in the dielectric properties of the lesions and the surrounding tissue.



The tiny gelatin-filled balloon Susan Hagness holds in her hand simulates a malignant breast tumor in studies that her group at the University of Wisconsin is conducting to develop an alternative to X-ray mammography.

GREG ANDERSON

The work builds on research Hagness did while still a grad student at Northwestern University (Evanston, Ill.). That project involved finite-difference time-domain (FDTD) algorithms for modeling the way electromagnetic waves propagate in dispersive materials, such as biological tissue. At Wisconsin, Hagness and her group have developed anatomically realistic FDTD models to study the cancerous breast. Using FDTD-computed backscatter signals and simple breast phantoms (used to simulate radiation interactions in the body), they've generated microwave images that clearly identify tumors as small as 2 mm in diameter. (X-ray mammography typically can't detect lesions smaller than 0.5 cm, and if the breast tissue is dense, a 1-cm or larger lesion may not show up.) The technology is still in the research stage, she cautions, and it may be years before clinical trials begin.

Early guidance

Hagness got an early start along her career path—in the fifth grade, to be exact. That's when Herb Bailey, a close family friend and a professor of mathematics at Rose-Hulman Institute of Technology in her home town of Terre Haute, Ind., began encouraging her talent in math. He persuaded Hagness to take computer programming during the summer, gave her math problems to solve, and entered her in Rubik's Cube competitions with him. By the time she was a high school senior, she was taking Bailey's differential equations course at Rose-Hulman.

Hagness also credits a junior high school teacher, Bob Fischer, who taught a math course that allowed students to work at their own pace. "Not only did he use novel teaching approaches, but he also had a commitment to his students that was unparalleled," says Hagness. "He made solving math problems and being part of the math team a blast."

Fischer may also have influenced her choice of a teaching career. "I didn't realize it at the time, but I learned a lot about how to be a good teacher from him," Hagness says.

Getting and giving support

While Hagness was contemplating college, Herb Bailey encouraged her to pursue electrical engineering. He himself had an EE degree and believed it would be a good match for her skills and interests in math and physics.

Hagness decided to apply to Northwestern University and to its recently created honors program in undergraduate research. Although she considered other schools, she was won over when Allen Taflove, a professor in the electrical and computer engineering department, called to encourage her to enroll at Northwestern. He later became her undergraduate advisor and Ph.D. advisor. In Taflove's lab, she worked alongside two graduate students, Melinda Piket-May and Rose Joseph.

"Thanks to their presence in the lab, I never experienced the sense of isolation that many women feel in this field, where they are still a small minority," explains Hagness. Taflove was also very supportive of women students, she notes. Of the 14 Ph.D. students who've graduated from his group, more than a third are women.

As a student and now as a teacher, Hagness has tried to be equally encouraging. Despite her heavy graduate school load, she taught computer classes at several high school outreach programs as well as linear algebra for Northwestern's Minority Engineering Opportunity Program. At Wisconsin, she sits on the faculty steering committee for the Women in Science and Engineering (WISE) Residential Program. The 120 or so college students in the program live together, take classes and workshops together, and attend social events. The results so far have been encouraging: WISE students typically have much higher first-semester grades than other students.

Another of her pet projects at Wisconsin is the College of Engineering's Graduate Women Network, which Hagness cofounded three years ago with Wendy Crone, an assistant professor of engineering physics. During a flight back from Washington, D.C., Hagness and Crone got to talking about the fact that women graduate students in the college had few chances to interact. They brainstormed, and thus the network was born. Today, its members gather for monthly lunch discussions on career issues and related topics and keep in touch through an e-mail listserve.

Vital Statistics

NAME: Susan C. Hagness

TITLE: assistant professor of electrical engineering, University of Wisconsin–Madison

BIRTHPLACE: Terre Haute, Ind.

EDUCATION: B.S. (1993) and Ph.D. (1998) in electrical engineering, Northwestern University (Evanston, Ill.)

RECENT HONORS: Booker Fellowship, National Academy of Sciences and U.S. National Committee for the International Union of Radio Science; invited participant, Frontiers of Engineering Symposium, National Academy of Engineering; Presidential Early Career Award for Scientists and Engineers

AFFILIATIONS: American Society for Engineering Education, IEEE, International Union of Radio Science, among others

Deciding to teach

Although Hagness finds working with students one of the best parts of the job, she didn't decide to go into academia until the end of her Ph.D. program. Northwestern had just introduced a new freshman engineering curriculum. Called Engineering First, it enables students to experience real engineering early on, and also integrates course content in physics, math, and so on, rather than teaching them separately. Hagness was the only grad student asked to help teach it.

To her surprise, Hagness found she enjoyed working with students. So, as she was preparing to graduate in 1998, she applied for several faculty jobs. She eventually settled on Wisconsin, where she could collaborate with researchers at the university's medical school. Another draw was that her husband, Timothy Dean, found work nearby; he's now the associate pastor at Luther Memorial Church in Madison. "I feel incredibly lucky," she says, "that we were able to solve the two-body problem"—the dilemma many professional couples face when seeking jobs in the same locale.

Hagness continues to enjoy her time in the classroom. "Finding ways to help students experience those 'aha!' moments is one of the aspects about teaching I enjoy the most," she says. Because many students struggle with electromagnetics, for example, she tries to come up with creative ways to help students visualize and develop an intuitive grasp of EM field and wave phenomena. She also relies on interactive computer animations to illustrate abstract concepts that defy mathematical analysis or experimental demonstrations. And just as Allen Taflove did with his students at Northwestern, Hagness encourages her undergraduates to get involved in her research. Such efforts have paid off: her courses consistently receive high marks on student evaluations, and in 2000, she received her department's Gerald Holdridge Excellence in Teaching Award.

"So much of the research I do has very long-term benefits," Hagness says. "Working with students offers me the opportunity to see nearly immediate benefits of my work. It's nice to finish up a day knowing that you have made a difference in someone's life."

Toward clinical trials

Meanwhile, Hagness' research proceeds apace. One project being funded by the National Cancer Institute of the U.S. National Institutes of Health involves determining the dielectric properties of malignant, benign, and normal breast tissue at microwave frequencies. There has been some disagreement on these properties, and obtaining accurate data is seen as critical to designing microwave detection systems that can discern, for instance, a benign cyst from cancer.

"Taking this technology from concept to clinical implementation requires a multidisciplinary team of investigators," Hagness points out. The team includes experts in radiology, oncology, biostatistics, surgery, microwave engineering, and signal processing.

"This area of research provides the most natural source of inspiration," she says. "There's never a day that goes by when I don't feel motivated." ●

Jean Kumagai, *Editor*