The newsletter of
The Acoustical Society of America

ECHOES

Volume 6, Number 1
Winter 1996

Active Noise Control

by C.E. Ruckman

This article is adapted from an Internet FAQ -- a list of answers to "Frequently Asked Questions" that arise repeatedly in Internet discussion groups. The complete text is available by anonymous ftp from rtfm.mit.edu, where the filename is: /pub/usenet/news.answers/active-noise-control-faq.

The question is often posed like this: "I heard about a new noise control technology called *Active Something-Or-Other*.... Can it make my house quiet when the kid next-door plays 'Black Sabbath' on his electric guitar?"

The buzzword for the technology in question is "active noise control," a.k.a. "active noise cancellation," a.k.a. "anti-noise," and it is one of today's hot research topics. Here is the bottom line: Yes, active noise control works in some circumstances, but no, you cannot use it to sound-proof an entire house.

Active control is sound field modification, particularly sound field cancellation, by electro-acoustical means. In its simplest form, an electronic controller drives a loud-speaker or other electromechanical actuator to produce a sound field that is an exact mirror-image of the offending sound (the disturbance). Sound from the speaker thus "cancels" the disturbance, and the net result is a significant reduction in sound.

The name differentiates "active control" from traditional "passive" noise control methods such as absorptive treatments, vibration mounts, or conventional exhaust mufflers. Passive techniques, important to nearly all products in today's increasingly noise-sensitive world, function best at middle and high frequencies. But the size and mass of passive treatments usually depend on the acoustic wavelength: they must be thicker and/or more massive for lower frequencies, a shortcoming not shared by active control systems.

Actually, the idea of active noise control was patented over 60 years ago by a German inventor. Paul Lueg's 1934 patent (see figure 1, page 4) is quoted almost universally as the dawn of active control research.

While the idea is not new, practical applications are. Research continued in the 1950s, but had little chance of becoming practical until the advent of modern digital computers and signal processing electronics. Active control became a mainstream research topic in the 1970s and 1980s, and in recent years research papers have been published at the rate of several hundred per year. Several companies now specialize in active control products, and the topic is

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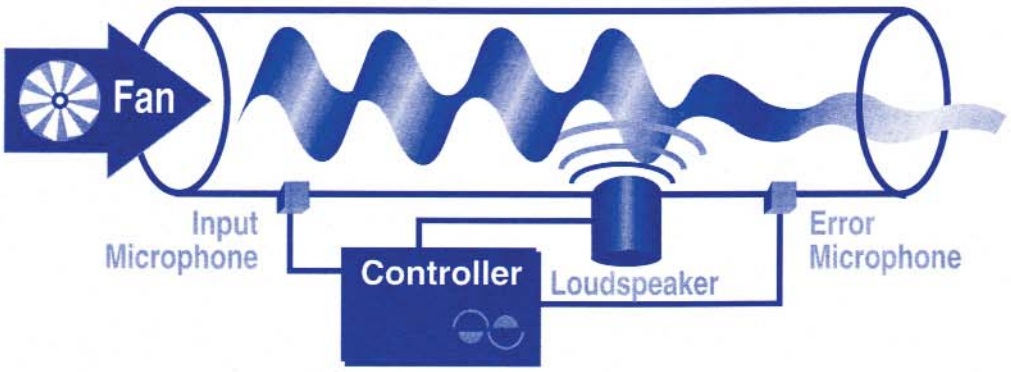

Courtesy of Digisonix, Inc. Middleton, WI.

We hear that...

ASA Past President and Silver Medal recipient **Floyd Dunn**, Professor Emeritus of the University of Illinois, is the 1995 recipient of the Institute of Electrical and Electronic Engineers (IEEE) "Engineering in Medicine and Biology" Career Achievement Award.

The University of Illinois has appointed **William D. O'Brien, Jr.** Director of the Bioacoustics Research Laboratory in the Department of Electrical and Computer Engineering to succeed Floyd Dunn upon his retirement.

Allan D. Pierce, another ASA Silver Medal recipient, has been presented with the Per Bruel Gold Medal for Noise Control and Acoustics during the recent meeting of the American Society of Mechanical Engineers in San Francisco.

Elizabeth A. Cohen, who served as the ASA Congressional Fellow in 1994, was elected by the Audio Engineering Society to the office of President-Elect (1996), which will be followed by a term as President (1997).

The University of Maine's College of Engineering Recognition Committee has presented its 1995 Distinguished Engineering Award to **Robert M. Hoover**, principal of Hoover & Keith, Inc., Houston, TX.

Sertoma International, a civic service organization, has presented its Howard P. House Award to **James Jerger**, Director of Audiology and Speech Pathology at the Baylor College of Medicine in Houston.

ASA's Vice President **Lawrence Crum** has been appointed to the International Commission on Acoustics, effective as of summer, 1996.

ECHOES

Newsletter of the Acoustical Society of America
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LETTERS TO THE EDITOR

More on the Hum

The feature article in the last issue of *Echoes*, "The Mystery of the Taos Hum," generated quite a bit of interest from the readers. At least four letters were received, by the authors or by the *Echoes* editor. Although lack of space prevents us from printing these letter, here is a summary of some of their key observations.

George H. Barnes of Wayne, PA reports that he experiences a very low frequency tinnitus on occasion, that seems to be below 28 Hz. Alfred Finck, Prof. Emeritus of Temple Univ. suggests that there may be pulmonary/cardio-vascular elements at work in the Taos Hum, and that changes in the perceived signal might be induced by vigorous exercise.

Richard K. Fullmer of Acoustical Engineers, Inc., Salt Lake City, has encountered this kind of phenomenon on several occasions over the past 20 years, and has found certain common factors:

- Low ambient noise level (usually well under NC-15),
- Quiet setting outdoors and indoors, very little activity in the dwelling, perhaps a single person living alone,
- Complainants likely to be 60 or older,
- Acoustician's inability to hear or measure the hum,
- Low-frequency masking noise usually eliminates hum perception.

George W. Kamperman of Kamperman Associates, Inc., Leesburg, FL writes that he has had a similar "hum" experience at his Wisconsin home, which is out in the country, surrounded by corn fields and cows. The hum is most apparent in the middle of the night and is easily detected because it is always accompanied by beats (about 2 seconds apart) between at least two signals. He has been able to measure the low-frequency tones and the beats. He first concluded that the source was a diesel engine manufacturing and testing facility in Waukesha, about 25 miles north of his home. But he has doubted this conclusion because: (1) the hum components he hears are more than 20 dB below published hearing threshold levels; (2) there are several hundred thousand residents living closer to Waukesha than he does with no known complaints; and (3) the hum's presence does not appear to be weather dependent, so he concludes that the source must be nearby.

Authors of the *Echoes* hum article, Joe Mullins and Jim Kelly, report that there is a "Taos Hum Home Page" on the Internet, which can be accessed as follows:

http://w.w.w.eskimo.com/~billb/hum/hum.html

There is also a Taos Hum Discussion List that can be subscribed to by sending this message:

subscribe taoshum-L your-email-addr-here

2nd Town Meeting held in St. Louis

"Societal Growth: How Big is Big Enough?" was the title of ASA's second Town Meeting, held at the recent meeting in St. Louis. Some 120 attendees heard three brief presentations, starting with Joe Dickey, who discussed statistics on the size of ASA, which now numbers about 7200 members. Dick Lyon gave some arguments in favor of encouraging growth, and expressed concern that other acoustical organizations seem to be growing faster than the ASA and absorbing new technical areas for which we might have been an appropriate home. Ira Hirsh supported a policy of continuing as we have been and not encouraging growth for its own sake. He expressed concern that the result of significant growth could be a cold, formal society in which meetings are not ideal places for scientific exchange.

Following these presentations, comments from the participants were solicited. Most suggested that we should make the ASA a welcoming home for emerging technical areas in acoustics, but that we should not mount a membership drive simply for the purpose of making the Society larger.

The Long Range Planning Committee, which sponsors the Town Meetings, will review the comments and make recommendations to ASA's Executive Council. Please send any comments on this subject to me at the Dept. Mechanical Engineering, Univ. Texas, Austin, TX 78712; e-mail: ilenebv@mail.utexas.edu; fax (512) 471-8727.

The focus of the next Town Meeting in Indianapolis will be "ASA Meetings: Are they Enough?" Once again, the Town Meeting will follow the plenary session. Comments on this topic, as well as on the meeting format, frequency, and style, may be made at the Town Meeting or to the Long Range Planning Committee at any time.

Ilene Busch-Vishniac,
Chair, Long Range Planning Committee

Women in Acoustics

At the recent meeting in St. Louis, the Executive Council voted unanimously to convert the ad-hoc Committee on the Status of Women into a full administrative committee with the title, Committee on Women in Acoustics. The new committee is charged with "... exploring and proposing activities designed to attract women to the profession of acoustics, to encourage women to join the Society, to assist women to become active participants in sessions and committees, and to stimulate women to seek and accept leadership positions in the Society." The committee's chair is Diana McCammon.

Animal Bioacoustics

Also at the St. Louis meeting, the Technical Specialty Group (TSG) on Animal Bioacoustics was approved as a full technical committee, with the change becoming official at the Honolulu meeting in the fall of 1996. The TSG came into the limelight at ASA during the controversy over the Heard Island Feasibility Test. The committee plans to hold sessions at upcoming meetings on low-frequency acoustic communication in animals (eg. elephants, hippos, and alligators), animal sound production, the effects of noise on animals, non-auditory physiological effects of noise, reptile bioacoustics, and within-species variation in acoustic signals.

If the ASA Marine Mammal Bioacoustics Short Course, held in Orlando on December 12-13, is any indication, the Animal Bioacoustics Committee may grow dramatically in the future. Co-organizers Whitlow Au and Ann Bowles had planned for 75-100 participants, but the final count was 230, which included individuals from all over the world. (The number of registrants ballooned after the registration form was posted on the World-Wide Web.) The course consisted of two days of tutorial lectures by recognized experts, starting with basic underwater acoustics, physiological and psychological acoustics, and acoustical techniques. These were followed by surveys of dolphin sonar, cetacean acoustic communication, long-range acoustic tracking techniques, automated recognition of marine mammal calls, and effects of noise on marine mammals. At the close, enthusiastic participants wanted to know when the next course would be held.

Calvin and Hobbes by Bill Watterson

(...noise control continued from page 1)

widely studied in universities and research laboratories.

How can adding sound make something quieter?

It may seem counter-intuitive to say that "adding sound" can reduce noise levels, but the method can and does work. Active noise control occurs by one, or sometimes both, of two physical mechanisms.

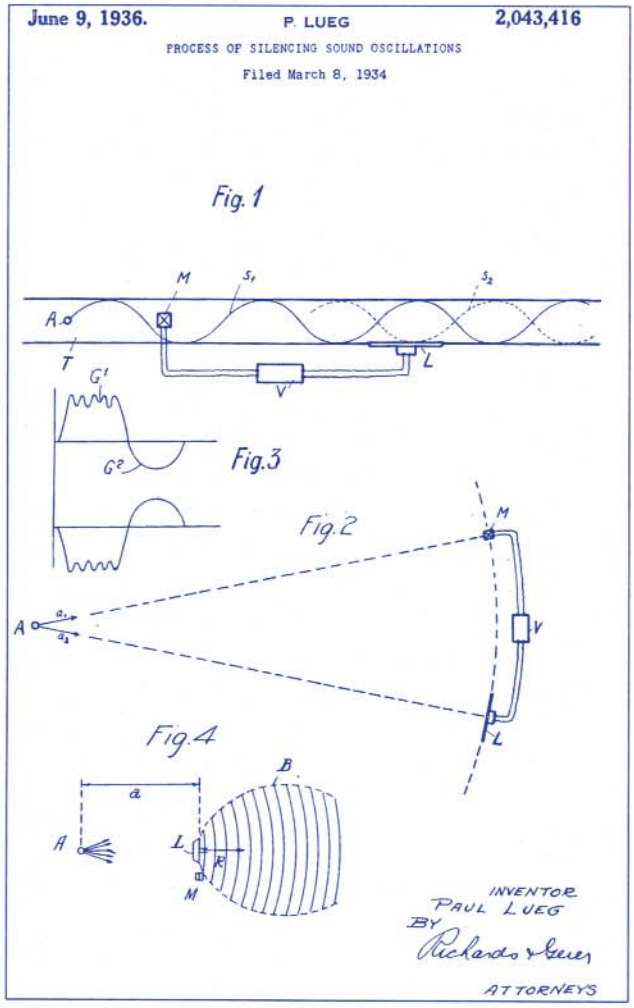

Fig. 1 Illustration from P. Lueg's U.S. patent, generally thought of as the earliest published work related to active noise control. (Actually, Lueg's German patent predates his U.S. patent by a few weeks.)

On the one hand, you can say that the active control system creates an inverse or "anti-noise" sound field that cancels the disturbance by destructive interference. Note that the anti-noise field must match the disturbance in both space *and* time -- a tricky problem indeed.

On the other hand, you can say that the control system changes the way the system "looks" to the disturbance, i.e., changes its input impedance. Consider the following analogy:

Picture a spring-loaded door that opens a few centimeters when someone pushes on it. A person on the other side is pushing the door so that it repeatedly opens, say, twice per second. Now suppose that whenever the other person pushes, you push back just as hard. Your muscles begin heating up, but the door actually moves less. You *could* say that you "anti-open" the door to "cancel" the opening, but you would not actually see the door opening and anti-opening. You could more accurately say that you change the impedance seen from the other side of the door: when the other person pushes, the door just doesn't move. (The spring-loaded door represents the spring effect of compressing air in a sound wave; it is not a perfect analogy, but it helps illustrate impedance coupling.)

When does active control work best?

Active noise control works best for sound fields that are simple in both space and time. To be spatially simple, the sound field must be of relatively low frequency (long wavelength) and/or must be restricted to a simple geometry. Temporal simplicity means that periodic or tonal disturbances are easier to control than transient or broad-band signals. When the neighbor's kid plays his electric guitar, the sound field surrounding your home is hopelessly complex because of the high frequencies, the complicated geometry of the house, and the time-varying spectral content. Conversely, the classical active control problem is a low-frequency tone traveling through a duct, an essentially one-dimensional problem that can often be controlled extremely effectively.

The emphasis on spatial simplicity dovetails well with the features of passive noise control methods, which tend to work best at higher frequencies. In reality, most active noise control systems combine passive and active techniques to cover a range of frequencies. For example, active exhaust mufflers usually include a low-restriction "glass-pack" muffler for middle and high frequencies, using active control only for the lowest frequencies.

What are some typical applications?

The most successful demonstrations of active control have been for enclosed spaces such as ducts, vehicle cabins, exhaust pipes, and headphones. Note, however, that few active noise control demonstrations have made the transition into successful commercial products.

One exception, active noise control headphones, has achieved considerable commercial success. Active headphones use destructive interference to cancel low-frequency noise while still allowing the wearer to hear mid- and high-frequency sounds such as conversation and warning sirens. Used extensively by pilots, active headphones are considered indispensable in helicopters and noisy propeller-driven aircraft. Originally selling for $1000 or more, some models now cost $200 or less.

Active exhaust and intake mufflers have also found success in commercial applications, though not to the same extent. Active mufflers have seen years of service on industrial compressors and generators. As unit prices for active automobile mufflers have fallen in recent years, sev-

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Active Noise Control

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eral automobile manufacturers are now considering active mufflers for future production cars. However, if you ask your local car dealer about the active muffler option on their latest model, you will probably receive a blank stare: no production automobiles feature active mufflers as of this writing.

Large industrial fans have also benefitted from active noise control. Loudspeakers placed around the fan intake or outlet not only reduce low-frequency noise downstream and/or upstream, but they also improve energy efficiency. In the right circumstances, they can pay for themselves within a year or two.

The idea of canceling low-frequency noise inside vehicle cabins has received much attention. Speakers in aircraft wall panels can reduce noise generated as the propeller tips rotate past the aircraft fuselage; such a system now flies on the new Saab 2000 and 340B+ aircraft. The key advantage is lower weight compared to purely passive treatments. In automobiles, the car stereo speakers can superpose cancellation signals over the normal music signal to cancel muffler noise and other sounds. One vehicle, currently offered only in Japan, includes such a system as a factory option. Unit cost is the primary obstacle for automobile use.

Other applications abound in such diverse fields as electrical power transmission, biomedical engineering, satellites and launch vehicles, and acoustic signature control for military vehicles. Most, though, are still experimental and are some years away from regular use.

What are the benefits of active control?

The practical benefits of active control technology are not all obvious at first glance. The main payoff, of course, is low-frequency quieting that would be too expensive, inconvenient, impractical, or heavy by passive methods alone. For example, the lead-impregnated sheets used to reduce cabin noise in propeller aircraft impose a severe weight penalty, but active control might serve the same function with a much smaller weight penalty.

Other possibilities reflect the range of problems to which active control can be applied. For instance, with conventional car mufflers the engine spends extra energy to push exhaust gasses through restrictive muffler passages. An active control muffler imposes less severe flow restrictions, thus improving performance and/or efficiency.

(Continued on page 7)

Spring Meeting

Indianapolis hosts spring ASA meeting

The home of the "Indy 500" will be the site of the ASA spring meeting, May 13-17 at the Hyatt Regency Indianapolis hotel. Members will have received the Call for Papers by the time *Echoes* goes to press, and can consult it for details such as hotel reservations, transportation, and signing up for the tutorial and short course. Assistive listening devices for individuals with hearing impairments will again be available and persons desiring this assistance should write to ASA's Woodbury NY office.

Here is a partial list of sessions highlighting the technical program:

- Effects of noise on animals
- Acoustics for hands free communications
- Reed instruments (including illustrations and performances)
- International regulations on hearing loss
- Current issues in automotive noise
- Workshop on therapeutic applications of medical ultrasound
- Physiology of the cochlea
- Pediatric cochlear implants

William Hartmann will present a tutorial lecture entitled "Pitch, Periodicity, and the Brain" on Monday May 13 at 7:00 pm. There will be a short course on "Community Noise" conducted by Eric Stusnick and Kenneth Plotkin on Sunday and Monday, May 12-13. Registration information for both programs is available in the Call for Papers or by calling ASA's Woodbury NY office at (516)576-2360.

A Distinguished Lecture, "Nonlinear Effects in Musical Instruments" will be presented by Neville Fletcher of the Research School of Physical Sciences and Engineering, Australian National University in Canberra. Professor Fletcher has co-authored with Thomas Rossing the well-known text, The Physics of Musical Instruments.

One new development will be the "students meet members" (no-host) luncheon. Interested students and members should contact James Sabatier at (601) 232-5404.

In addition to the Indianapolis Motor Speedway and its Hall of Fame Museum, the city offers several other attractions, less famous but perhaps more appealing to ASA members, guests, and families.

Indianapolis boasts the world's largest children's museum, with hands-on interactive learning in natural and physical sciences, world culture, history, the arts, and computers. Other points of interest include a large zoo, the Indianapolis Museum of Art, the Eiteljorg Museum of American Indians and Western Art, and the "Conner Prairie," a recreation of an 1836 pioneer village, complete with games and crafts. There's plenty to do besides acoustics in Indianapolis.

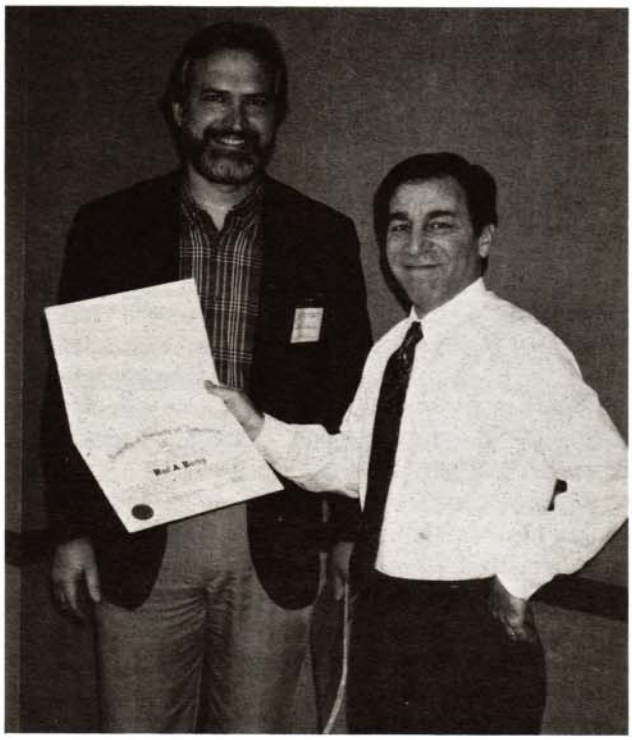
ASA speeds along information highway

Under the leadership of Paul Baxley and the ASA Public Relations Committee, the Society has inaugurated a "World Wide Press Room," to be active just before and during each semi-annual meeting. The purpose is to provide information on the ASA and the field of acoustics to the news media, science writers, and other interested parties. This includes press releases on meetings, lay language versions of papers to be presented at meetings, notices of special events, and links to the ASA Home Page.

An experimental version of the Press Room was demonstrated at the St. Louis meeting with a phone-line connection to the Internet. Plans include the ability to access the home page over the internet at future meetings, and a lap-top computer should be available for these purposes at the Indianapolis meeting. Policies are currently being developed for the submission of information to be included in the Press Room.

The Executive Committee set up the ad hoc "Home Page Publishing Committee," co-chaired by Paul Baxley and Carr Everbach, to provide guidance to each of the Technical Committees in developing its own home page.

In case anyone missed the home page site in the previous issue of *Echoes*, it is: http://asa.aip.org/



President Bob Apfel (right) presents Paul Baxley with a certificate of appreciation recognizing his work on ASA's Home Page and World Wide Press Room.

Call for experiments

ASA's Committee on Education in Acoustics has decided to revise and update its laboratory manual, "Suggested Experiments for Laboratory Courses in Acoustics and Vibrations." The previous edition was issued in 1972 and the Committee is soliciting modern experiments. Topics could include anything appearing in "Lindsay's Wheel of Acoustics," but exercises in fundamentals are of primary importance. Contributions should include:

- Purpose of the experiment
- Theoretical model
- Measurements
- Reporting and evaluation of results
- Equipment required
- References

Contributors should indicate whether the experiment has been performed and give comments on its teaching effectiveness. The editor will determine inclusions, and reserves the right to edit contributions. Contributions should be sent by May 1, 1996 to: Prof. Elmer Hixson, Dept. Elect. & Computer Eng., Univ. Texas, Austin, TX, 78712-1084. Phone: (512)471-1294; fax: (512)471-5553; e-mail: ehixson@mail.utexas.edu.

Infant linguistics

Four thousand members of the Society for Neuroscience heard Patricia Kuhl (ASA Vice-President Elect) give that society's Presidential Address at their annual meeting in November 1995. The title of the talk was "Brain and language: Linguistic experience forms the brain's perceptual maps for speech." Dr. Kuhl pointed out that infants discriminate among all phonetic units used in the world's languages, but as adults, our abilities are greatly reduced. Linguistic experience alters the way in which the brain processes speech; it "warps" the perceptual space underlying speech, accounting for both language-specific listening and the "accents" that indelibly mark speech.

Information from the address and from an interview with Dr. Kuhl was reported in the *San Diego Union-Tribune* and can be expected to appear later in the spring in *The New York Times*.

Way cool acoustician

Move those baseball and football cards over and make room for the "Way Cool Scientists." Bill Nye, "The Science Guy," hosts a program for kids on PBS in which he answers some basic science questions, suggests do-it-at-home experiments, and designates prominent U.S. scientists as Way Cool Scientists. One of these notable scientists is ASA's recent Silver Medal winner, James West, whom Bill Nye has recognized because of his many years of studying directional sound perception and his co-invention of the foil electret microphone used in telephones, hearing aids, and tape recorders. Jim is now immortalized on a Way Cool Scientist card, which can be traded, sold, or treasured by budding scientists.

Society Pages

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Additional benefits might include:

- increased material fatigue life,
- lower energy usage, as with industrial fans,
- lower facility operating costs due to reduced maintenance downtime,
- improved ergonomics and reduced operator fatigue.

What lies ahead for active control?

The challenge facing researchers is to make refinements that will lead to widespread practical use and commercial success. Most applications have not yet achieved their full potential. Among the reasons: systems for high-unit-volume applications (automobiles, appliances) are too expensive, and systems for low-unit-volume (aircraft, military applications) provide marginal payoffs. Continued research holds much promise as improved hardware and design methods spur steady, if incremental, advances in the state of the art.

Dr. Christopher Ruckman, a research engineer at the Naval Surface Warfare Center, was recently named Carderock Division Employee of the Year. He also received the 1994 ASA Science Writing Award for Professionals in acoustics for his work on the Active Noise Control FAQ. He may be reached via e-mail at ruckman@oasys.dt.navy.mil.

Don't shelve that Directory!

Or if you do shelve it, make sure it's within arm's reach. Many members don't realize what a valuable resource the ASA Membership Directory and Handbook is. It lists all members of the Society, as well as how to get in touch with them. Did you just read a great paper in the Journal and have a burning question about it? Give the author a call, or if you choose, send him or her an e-mail. Most authors are pleased to discuss their work. If you're a student doing a dissertation, you might ask other ASA members in your specific field if they know of anyone else studying or publishing on the same topic. Sending one e-mail might save you from having to change topics halfway through your research! Or perhaps you're moving to a new town or visiting a foreign city and you want to contact someone there in your field. Take a look in the back of the directory, where members are arranged geographically and according to technical field. Also, in the front are all sorts of interesting data, such as medal winners, present and past officers, committee members, information on the growth of the Society, and a list of acoustical societies around the world. When the Directory/Handbook arrives, give it a quick scan and keep it within arm's reach.

–Charles Schmid, ASA Executive Director

Acoustics In the News

Newspapers

The New York Times featured several articles on acoustics over recent months. On Oct. 3, the article "Songbird Migrations Tracked With Nocturnal Eavesdropping" by Les Line concerned research at Cornell University's Ornithology Laboratory. Listening stations have been developed to monitor the calls of various migrating birds, and computer programs are being perfected to identify each bird's call and estimate how many of each species pass over a particular site. Later that month *The Times* carried an article by Malcolm W. Browne entitled "Deep Solar Rumblings May Offer Key to Sun's Inner Structure" (10-24-95). The author describes the Global Oscillation Network Group (GONG), which should yield valuable information on the Sun's interior by studying the sound waves trapped in the Sun's spherical cavity. It is hoped that the GONG system will answer questions like: Why does the Sun have spots? and How long will the Sun sustain life on Earth?

Other items of interest in *The New York Times* include the article by music critic Anthony Tommasini, "The Sound of Music in a Revered Boston Hall" (10-31-95), in which the author discusses renovations and changes in the acoustics of Jordan Hall at the New England Conservatory; and "'Glasses for the Ears' Easing Children's Language Woes" (11-14-95) by Sandra Blakeslee, which describes a special form of computer-generated speech to train language-disabled children to hear sounds they couldn't hear before. This temporary treatment is expected to make permanent changes in the targeted areas of the brain. On November 7, the article by William J. Broad, "Ocean Study to Start After Big Changes and a Long Delay" reports the resumption of the ATOC experiment to chart ocean temperatures through acoustics.

Then, in the November 16 *Los Angeles Times*, Richard C. Paddock reports that the ATOC experiment was discontinued indefinitely after the discovery of three dead whales in the area of the experiment, "Whale Deaths Halt Sonic Experiment." [*Echoes* has just learned that ATOC is back on track as of Dec. 2, and an investigation into the whale deaths indicates that ATOC's signal was not responsible.]

Elsewhere in the nation: The *Dallas Morning News* featured the new developments in guitar research and design that were reported at ASA's Washington DC meeting in the article "Physics Unplugged" by Alison Mack (10-9-95). In an article entitled "More than idle chat," reporter Ronald Rosenberg describes the

commercial applications of speech recognition systems, emphasizing Massachusetts companies capable of recognizing 40,000 to 60,000 words, backed up with 120,000 to 200,000 word dictionaries. In the November 2 issue of *The Oregonian*, Richard L. Hill reports on the development of a portable ultrasound instrument that will detect and treat internal bleeding, "Ultrasound: a new wave." In the same issue, Mr. Hill also presents a discussion of sonoluminescence, "Scientists look inside tiny bubbles." Both articles feature the research of Lawrence A. Crum. In "Babies store parents' patter to learn language," David Graham provides excerpts from Patricia Kuhl's presentation at the Society for Neuroscience on children's learning of language (*San Diego Union-Tribune*, 11-15-95).

Science magazines

The Neuroscience meeting was also featured in the December 1 issue of *Science* in three short pieces by Marcia Barinaga, all touching on acoustical topics. In "Vive la Difference" the author describes research by scientists from McGill University on the extra brain-power needed by speakers of a second language, even though they are fluent in that language. In "Baby Sparrows Thrive on Word Salad," researchers found that baby birds, in a way that parallels the process of infant humans, distinguish the song of their species by responding to the song's individual sounds. "Stuttering Comes Into Focus" summarizes research indicating that modern brain imaging techniques should help locate the origins of stuttering.

Also of interest in *Science* are the articles "Magnetic Resonance Elastography by Direct Visualization of Propagating Acoustic Strain Waves" by R. Muthupillai, D.J. Lomas, P.J. Rossman, J.F. Greenleaf, A. Manduca, and R.L. Ehman (9-29-95); and "Speech Recognition with Primarily Temporal Cues" by R.V. Shannon, F-G Zeng, V. Kamath, J. Wygonski, and M. Ekelid (10-13-95). Joshua Fishman reports on the November meeting of the Society of Vertebrate Paleontology, in which scientists argued that the middle ear ossicles originated as hinges between the jaw and skull, and migrated to their present site because of a prolonged period of brain growth. This "ear migration" is repeated in the fetal development of every mammal.

The weekly publication *New Scientist* contains two recent articles of interest to acousticians. In the article, "What's in a Voice" (9-23-95), ASA Fellow Ingo Titze explores the science of the singing voice, outlining many of the physiological characteristics of the well-trained and pleasing voice. (See also the feature article by Ingo Titze in *Echoes*, vol. 4, no. 2, 1994.) In "Music for the senses," Rosie Mestel cites the dearth of home-made music in today's world and describes the development of new, "user-friendly" instruments for everyone to play (10-21-95).

Ivars Peterson reported on the session on sonic booms at the ASA meeting in Washington DC last May in the September 23 issue of *Science News*. In "Sonic Impact" he describes progress on the continuing search for ways to reduce the intensity and adverse effects of sonic booms.

Radio and other media

National Public Radio aired two programs on the development of language in infants. The first was reported by Judy Woodruff during the first week of October, and the second by Michele Trudeau on November 25. Both included interviews with Patricia Kuhl. Earlier in the fall (10-10-95), "Morning Edition" aired a piece on the acoustics of Carnegie Hall and the discovery of solid concrete of mysterious origin beneath the floorboards. [Interested readers may wish to note that Leo Beranek mentions Carnegie Hall's wood-over-concrete floor in his 1962 book, *Music, Acoustics, and Architecture.*]

Physics News Update, the weekly electronic bulletin on physics written by Phillip Schewe and Ben Stein has included two summaries on acoustics in recent weeks. "Isotope Effects in Sonoluminescence" appeared on October 25, and "Acoustic Time-Reversal Mirrors (TRMs) on November 21. The series is available from the American Institute of Physics.

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