Session 4aAA

Architectural Acoustics and Noise: Acoustical Issues of Green Buildings

Brandon D. Tinianov, Chair
Serious Materials, 1250 Elko Dr., Sunnyvale, CA 94089-2213

Chair's Introduction—8:00

Invited Papers

8:05

4aAA1. Comparing acoustical requirements of green building assessment systems. Amy Costello and Kenneth Roy (Armstrong World Industries, ABP Technol., 2500 Columbia Ave., Lancaster, PA 17604, aacostello@armstrong.com)

As the Green Building movement gains momentum, more buildings are being evaluated and rated using the environmental assessment systems. A number of these systems now include acoustical requirements or award points for achieving a certain level of acoustical performance. However, how do these environmental assessment systems compare in terms of acoustical requirements? This paper examines and compares some of the leading national and international environmental assessment systems including LEED, BREEAM, Green Globes, and Collaborative for High Performance Schools, and evaluates the importance that acoustical performance is playing in green building rating systems.

8:25

4aAA2. Why has it been so difficult to add acoustics to the criteria of the Leadership in Energy and Environmental Design green building rating system? Ralph Muehleisen (Civil, Architectural, and Environ. Eng., Illinois Inst. of Technol., Chicago, IL 60616, muehleisen@iit.edu)

Leadership in Energy and Environmental Design (LEED) is the most popular green building rating system in use in the United States. There are LEED rating systems for a variety of different building types. The LEED system rates the sustainability and performance in several categories including the indoor environmental quality (IEQ). While LEED incorporates many important IEQ factors including air quality and daylighting in all the rating systems, acoustics has been included only in LEED for schools and the soon to be released LEED for healthcare. The development and subsequent modification of the acoustics portion of LEED for schools highlights some of the problems involved with modifying LEED to include acoustics and some of the issues involved in implementing a LEED rating system that includes acoustics. This paper will discuss why including acoustics within LEED rating systems has been and will continue to be problematic.

8:45

4aAA3. Leadership in Energy and Environmental Design for schools: Unintended consequences? Going "green" and the implications on classroom acoustics. Molly Norris (Threshold Acoust., 53 W. Jackson Blvd., Ste. 1734, Chicago, IL 60604, mnorris@thresholdacoustics.com)

The advent of the LEED for Schools Minimum Acoustical Performance criteria is a welcome step in the development of green building design. Recent experiences with trying to meet these criteria have led to frustration on the part of architects and the subsequent relaxation of the criteria by the USGBC into a more attainable structure. While the movement to incorporate green design is imperative, the relaxed acoustic criteria may actually be counterproductive in achieving a reasonable acoustic environment for learning. Has good acoustic practice been sacrificed for the green label and is it worth it? A recent case study will be presented.

9:05

4aAA4. A Leadership in Energy and Environmental Design study of Philadelphia Schools; What is old is new again. Felicia Doggett (Metropolitan Acoust., LLC, 40 W. Evergreen Ave., Ste. 108, Philadelphia, PA 19118)

The Philadelphia School District has a stock of over 90 school buildings listed on the National Register that were constructed between 1920 and 1940, most of which are still in use today. With a minimum size of 50 000 sq ft per building, this resource of over 5×10^6sq ft of building area is likely to remain in use for at least another generation. The classrooms in the buildings are very similar in construction consisting of large windows, narrow floor plates, and concrete construction. The School District has also adopted the policy that every one of their new and renovated schools will be LEED certified under LEED For Schools 2007. Since it is not practical to raze these buildings, what can be done to meet the LEED certification? It is surprising how "green" they are. What is old is new again.

9:25

4aAA5. Case study: Leadership in Energy and Environmental Design Platinum office building with innovation credit for acoustic design. Kenneth Roy, Amy Costello, and Anita Snader (Armstrong World Industries, ABP Technol., 2500 Columbia Ave., Lancaster, PA 17604, kproy@armstrong.com)

During the fall of 2006, an existing corporate office building in Lancaster, PA was registered with USGBC for Leadership in Energy and Environmental Design (LEED) certification. In the spring of 2007, this building was awarded the highest achievement, a LEED-EB Platinum rating, only the sixth such award nationwide at that time. This level of performance was due in part to the achievement of an Innovation Credit 1.3 for superior acoustics. The building IEQ postoccupancy survey was evaluated by using the UC Berkeley, Center for the Built Environment, on-line survey tool. The survey results indicated problems with speech privacy performance in the open plan spaces, and a balanced design approach was taken to resolve that issue. Since this was the first such application for an innovation credit on the basis of acoustic design, it was first necessary to provide USGBC with proof that the acoustic environment does affect the health and performance of occupants and that a superior acoustic design can be developed compared to what is generally considered a typical design.

9:45

4aAA6. Green hospitals: Acoustical challenges and opportunities. Kenric Van Wyk (Second Fl., 124 Fulton St. East, Grand Rapids, MI 49503, kvanwyk@acousticsbydesign.com)

The United States Green Building Council and Green Guide for Healthcare have each adopted portions of the new American Institute of Architects (AIA) Interim Sound and Vibration Design Guidelines as the Reference Standard as points for their rating system. This paper gives a brief overview of the AIA guidelines, how they are addressed by these two leading sustainability rating systems, and how they impact the design of future healthcare facilities. Sustainable practices are changing to include acoustics and vibration design. However, even the best intent has some of its own challenges. How will healthcare facility design benefit from these design changes to include sound and vibration and what are the potential pitfalls?

10:05—10:15 Break

Contributed Papers

10:15

4aAA7. Case study of the acoustical analysis for three leadership in energy and environmental design for school applications. Threcia Robinson (Siebein Assoc., Inc., 625 NW 60th St., Ste. C, Gainesville, FL 32607, trobinson@siebeinacoustic.com), Gary Siebein (Univ. of Florida, Gainesville, FL 32611-5702), Adam Bettcher, and Chris Jones (Siebein Assoc., Inc., Gainesville, FL 32607)

Case studies of the leadership in energy and environmental design (LEED) analysis of an elementary school, a high school, and a college academic building were conducted. The case studies included field measurements of reverberation times within core learning spaces, noise insulation class ratings of walls between classrooms and other rooms as well as between classrooms and the exterior, and noise from building systems. The field measurements demonstrated that reverberation times generally met the criterion as designed. The walls between classrooms and walls between classrooms and other spaces generally required improvements to meet the LEED criteria. Noise from building systems generally met the 0 EQ point criterion. Few if any rooms met the +1 or +2 point requirement without special acoustical design including reduced air velocities, adding silencers in supply and return ductwork and moving terminal boxes and fan coil units out of the classroom spaces. Rooms adjacent to the mechanical rooms also generally exceeded the 45 dBA criterion for background noise due to both sound transmitted through the walls and through short duct runs. The study shows that standard school construction practices will have to be modified to meet the LEED for school criteria.

10:30

4aAA8. Leadership in energy and environmental design for schools 2009 acoustics prerequisite and credit evolution and future direction. Alexis Kurtz (Arup, 155 Ave. of the Americas, New York, NY 10013, alexis.kurtz@arup.com), Daniel Bruck (BRC Acoust. Technol. Consulting, Seattle, WA), David Lubman (DL Acoust., Westminster, CA), and Charles Salter (Charles M. Salter Assoc., Inc., San Francisco, CA)

In May 2008, the U.S. Green Building Council (USGBC) released an updated acoustics prerequisite and credit for inclusion in the Leadership in Energy and Environmental Design for Schools 2009 Rating System. Guidance for the update was provided to the USGBC by the four acousticians in the Indoor Environmental Quality Technical Advisory Group, which focused on identification of key acoustical metrics and development of the credit for greater acceptance within the design and construction community. This paper discusses the process and challenges of balancing market factors, cost, and effective acoustical design for classrooms. The resulting prerequisite and credit are intended to be easily attainable within reasonable cost constraints for classrooms in all geographic regions of the United States. Future direction for classroom acoustics in green design, implications arising from poor classroom design, and the need for greater involvement of the acoustics community in credit development will also be discussed.

10:45

4aAA9. Classroom acoustics in green schools. Pamela Harght and Robert C. Coffeen (School of Architecture and Urban Planning, Univ. of Kansas, 1465 Jayhawk Blvd., Lawrence, KS 66045)

Green schools are becoming increasingly common as school districts continue to experience a rapid growth in population. These schools promote academic success and higher retention rates as well as healthier environments with cleaner air and more daylight as compared to their nongreen counterparts. However, green buildings have become synonymous with poor room acoustics because many of these green goals often result in compromising acoustics and noise control with green building implementing natural ventilation, radiant cooling, and green materials, to name a few. This paper will examine the current conditions of room acoustics in classrooms based on field tests for reverberation, background noise levels, speech intelligibility, and noise isolation from adjacent spaces in addition to the overall design of the classroom. In addition to testing, results from an electronic questionnaire issued to those who teach in these green environments on a daily basis will be discussed. This questionnaire addreses common problems in classroom acoustics in additon to seeking feedback on this new teaching environments. Finally, the role of acoustics in Leadership in Energy and Environmental Design for schools, the process for acoustical consultants for certifying a school, will be discussed.

11:00

4aAA10. Geothermal heat pumps and acoustics for people who do not know much about geothermal heat pumps. Michael Ermann (School of Architecture + Design, Virginia Tech, 201 Cowgill Hall, Blacksburg, VA 24061-0205, mermann@vt.edu)

Geothermal heat pumps operate more efficiently than traditional heat pumps and air conditioners–much more efficiently–and have no noisy outdoor equipment. Yet, after inquiries to mechanical system manufacturers and to the Technical Committee on Architectural Acoustics Green Building Acoustics Subcommittee listserv, I have not found instances where these systems are specified for their acoustic performance. This paper presents a short tutorial on the basics of geothermal systems (also called geoexchange systems or ground-source-coupled heat pumps) geared to those without significant prior knowledge.

11:15

4aAA11. Leadership in Energy and Environmental Design (LEED) for schools: Providing room acoustics for classrooms that is affordable, green, and meets requirements. Joseph F. Bridger, Steven S. Stulgin, and Mathew M. George (Stewart Acoust. Consultants, 7406 L Chapel Hill Rd., Raleigh, NC 27607)

Leadership in Energy and Environmental Design (LEED) for schools has added classroom acoustics (based on ANSI S12.60) to the prerequisite for all K-12 schools seeking the U.S. Green Building Council LEED certification and several points for achieving additional measures. LEED for schools' room acoustics requirements are the same as the classroom acoustics standard. The U.S. Green Building Council has made it a prerequisite to receive certification for all K-12 schools. This paper explores how to achieve the requirements, while keeping it affordable and green.

11:30

4aAA12. Leadership in Energy and Environmental Design for schools: Designing mechanical system noise control to be green, affordable, and meet requirements. Joseph F. Bridger, Steven S. Stulgin, and Mathew M. George (Stewart Acoust. Consultants, 7406 L Chapel Hill Rd., Raleigh, NC 27607)

Leadership in Energy and Environmental Design (LEED) for schools has added classroom acoustics (based on ANSI S12.60) to the prerequisite for all K-12 schools seeking the U.S. Green Building Council LEED certification and several points for achieving additional measures. The Background Noise Level requirements of LEED for schools (U.S. Green Building Council) have several different compliance paths to meet the requirements. This paper explores the pros and cons of each and shares experience on how to design the HVAC noise system to meet the requirements for typical green building designs.

THURSDAY MORNING, 13 NOVEMBER 2008 LEGENDS 2, 8:30 A.M. TO 12:00 NOON

Session 4aAB

Animal Bioacoustics: Acoustics of Manatees, Alligators, and Other Topics

Jennifer L. Miksis-Olds, Cochair
Pennsylvania State Univ., Applied Research Lab., P.O. Box 30, State College, PA 16804

Ann E. Bowles, Cochair
Hubbs Sea World Research Inst., 2595 Ingraham St., San Diego, CA 92109

Chair's Introduction—8:30

Invited Papers

8:35

4aAB1. What can we learn from studying manatee vocalization patterns? Jennifer L. Miksis-Olds (Appl. Res. Lab., The Penn State Univ., P.O. Box 30, State College, PA 16804, jlm91@psu.edu)

Vocalizations are assumed to form the basis of most long range communication in manatees, so studying how animals naturally use their vocalizations can provide insight into many aspects of the manatee acoustic communication system. Vocalizations were recorded from manatees in Sarasota Bay, FL over two nonwinter seasons. Recordings were made under a variety of conditions spanning different habitats, social groupings, behavioral states, environmental sound levels, and observation methods. Analysis of vocalization patterns indicates that manatee vocalization usage is highly context dependent. Patterns were observed to be a function of calf presence, behavioral state, and environmental sound levels. Additionally, vocalizations tended to separate into two distinct call types. Observed patterns will be discussed in the context of communication theory. Further analysis of the dataset has the potential to offer information relating to signal evolution, call function, and impacts of noise on manatee communication and behavior.

8:55

4aAB2. Vocal behavior of Florida manatees during vessel approaches. Douglas Nowacek (Nicholas School of the Environment and Earth Sci., Pratt School of Eng., 135 Duke Marine Lab Rd., Beaufort, NC 28516, dpn3@duke.edu) and Athena Rycyk (Florida State Univ., Tallahassee, FL 32306)

Florida manatees (*Trichechus manatus latirostris*) spend much of their lives in an "urbanized" ocean with high levels of vessel traffic being common during much of the year. To explore the detailed acoustic and motor behavior of manatees during vessel approaches, digital archival tags were attached to animals in the waters of southwest Florida in 2007 and 2008. These tags record sounds produced

by the manatee and other sounds in the environment up to 32 kHz as well as sampling a suite of behavioral and environmental sensors at 50 Hz. The vocal behavior of manatees before, during, and after vessel approaches was investigated. Vocalizations were assigned to the tagged manatee by the higher amplitude and the presence of higher frequency harmonics compared to signals produced by nearby animals. Dolphins have been found to increase their vocalization rate at the onset of vessel approaches, and we have numerous vessel approaches to 20 individuals to evaluate manatee vocal behavior in these contexts. We will present results from single as well as multiple boat approaches and compare these vocal rates to periods without boats. In addition to reporting vocalization rates during vessel approaches, we are investigating the types of signals used by manatees in these situations.

9:15

4aAB3. Technical challenges in the acoustic detection of manatee vocalizations. Christopher Niezrecki (Dept. of Mech. Eng., Univ. of Massachusetts Lowell, One University Ave., Lowell, MA 01854, christopher_Niezrecki@uml.edu)

Over the past several years there has been much interest in detecting the West Indian manatee (*Trichechus manatus latirostris*) in heavily used waterways to reduce the number of collisions with watercraft. The successful detection of manatee vocalizations at an appreciable range in the natural environment is largely dependent on the background noise levels. The background noise consists primarily of boat and snapping shrimp noise as well as other animals and natural sources of noise. In order for effective detection to be realized, advanced signal processing techniques must be used. Within this work, the scope of the problem is presented and some of the technical hurdles are described. Several advanced signal processing algorithms (to reduce background noise) are described and their effectiveness is presented.

9:35

4aAB4. Overall hearing abilities of manatees and ecological acoustical challanges. Edmund Gerstein, Laura Gerstein, Joseph Blue (Leviathan Legacy Inc., 1318 SW 14th St., Boca Raton, FL 33486), and Steven Forsythe (U.S. Naval Undersea Warfare Ctr. Div. Newport, Newport, RI)

A comprehensive series of underwater psychoacoustic tests was conducted to measure the hearing abilities of West Indian manatees. Pure tones, complex and real world sounds were presented to manatees under controlled acoustical conditions. The results from 30 000 threshold trials measured their audiogram, temporal integration, critical ratios, MMAs and directional hearing. Complementing these investigations, underwater acoustical measurements of manatee habitats and vessel noise propagation were conducted to evaluate acoustical factors that render Florida manatees vulnerable to repeated collisions with vessels. Both low-frequency cutoffs in shallow water and near surface boundary effects limit the propagation of the dominant low-frequency spectra from slow moving boats. Slow speed zones implemented to protect manatees do not address this underlying acoustical challenge. Ironically, the strategy can be counterproductive in turbid waters and can exacerbate the problem, making vessels more difficult or impossible for manatees to detect while increasing transect times and the opportunities for collisions. While manatees are not adapted for hearing the dominant low-frequency spectra from a slow watercraft, they are well equipped to detect and locate higher-frequency modulated sounds. This provides a narrow sensory window through which to alert manatees of approaching vessels. A specially designed alarm to alert manatees is being tested. [Work funded by the U.S. Department of Defence Legacy Resource Management Program, Navy, Florida Inland Navigation District, and Florida Fish and Wildlife Conservation Commission.]

9:55

4aAB5. Problems and issues in low-frequency aquatic communication. Neil Todd (Faculty of Life Sci. Univ. of Manchester, Manchester M60 1QD, UK, neil.todd@manchester.ac.uk)

A recent study concerning the production, transmission and reception of alligator vocalizations has indicated that there are significant gaps in our knowledge of the physiology and physics of low-frequency sound communication in air and water [Todd, J. Acoust. Soc. Am. **122**, 2906–2915 (2007)]. In this paper these issues are discussed, and some possible solutions are considered for aquatic communication by both amphibians and crocodilians in the light of some other recent data on frog vocal behavior in water.

10:15—10:30 Break

Contributed Papers

10:30

4aAB6. Field tests of a directional parametric acoustic alarm designed to alert manatees of approaching boats. Edmund Gerstein, Laura Gerstein, Joseph Blue (Leviathan Legacy Inc., 1318 SW 14th St., Boca Raton, FL 33486), Josiah Greenewald, and Narayan Elasmar (Florida Atlantic Univ., College of Sci., 777 Glades Rd., Boca Raton, FL 33431)

The efficacy of the alarm was documented during controlled slow boat approaches under two experimental conditions: (1) approaches without an alarm and (2) same boat approaches with an alarm. Experiments conducted in a NASA security area provided controlled environmental conditions and minimized anthrogenic acoustical variables. An array of GPS instrumented buoys were deployed to acoustically and visually grid sites. HD aerial video synchronized with these buoys documented behavior and acoustic conditions at focal animal positions and throughout sites. Bathymetry and propagation measurements indicate shallow water constraints along with Lloyd's mirror effect resulting in significant transmission losses at frequencies of 1 kHz. This could account for the lack of response observed during 94% of the boat approaches without the alarm. In contrast, 100%, of the alarm approaches elicited overt avoidance responses. The change in behavior during approach trials was significantly greater during alarm trials $F=76.74$, df$=1$, $p<0.01$). The distance at which manatees responded was significantly greater during alarm trials ($F=143.42$, df$=1$, $p<0.01$). Applying conservative critical ratio estimates for wideband noise, manatees could not detect no-alarm approaches at distances of 9 m, while manatees responded to alarm

approaches up to 35 m away at levels 18 dB above their estimated critical ratios. [Work funded by the U.S. Department of Defence Legacy Resource Management Program, (Navy), Florida Inland Navigation District, and Florida Fish and Wildlife Conservation Commission.]

10:45

4aAB7. Ultrasonic hearing and vocalizations are used in communication by West Indian manatee mothers and calves. Edmund Gerstein, Laura Gerstein, Joseph Blue (Leviathan Legacy Inc., 1318 SW 14th St., Boca Raton, FL 33486), and Steve Forsythe (U.S. Naval Undersea Warfare Ctr., Div. Newport, Newport, RI)

Ultrasonic hearing thresholds above 46 kHz were first measured with a test-sophisticated manatee in 1997. Using staircase and method of constants paradigms, pure tones (38–96 kHz) were presented in force-choice two-alternative tests. Repeatable detection thresholds were measured at 38, 46, 56, 66, and 76 kHz. These extended ultrasonic hearing results precipitated additional tests using the CHP-87-L acoustic tag, which regulatory biologists routinely attach to manatees. The tag produces a 75 kHz pulsed tone at 155 dB. The received SPL at manatee ears approximates 149 dB. Over a tag's 2 year life expectancy, permanent selective hearing loss may occur. This is a concern because ultrasonic hearing may be important for directional hearing and communication between mothers and calves. Using a four hydrophone array, calls between wild mothers and calves were sampled at 100 kHz. Individual callers were localized, and some individuals could be identified. Peak source levels of 121 dB *re* 1 Pa at 2 m were directly recorded with significant energy (103 dB) at 46 kHz. These calls are highly directional and were only documented when manatee callers were positioned on axis with a hydrophone's acoustic center. Vigorous duets between calves and mothers had call rates up to 20 calls/min.

11:00

4aAB8. Detection and classification of underwater movements with an in-air biosonar system. Maosen Wang (School of Mech. Eng., Nanjing Univ. of Sci. Technol., Nanjing, 210094, Peoples Republic of China, maosen.wang@gmail.com) and Andreas Zell (Tuebingen Univ., 72076, Tuebigen, Germany)

The aim of this work is to take advantage of the perceived properties of fishing bats. An in-air biosonar system on a mobile robot is presented for the detection and classification of tiny movements under the water surface. Detecting and classifying underwater turbulence with in-air biosonar system allows mobile agent to sense underwater movement without dipping transducers into water. In this work, both fishes—4-cm long goldfish—and waterproof motors (3-W power, 2-cm diameter) are used as sources to generate underwater turbulence. According to real-time feedback results from digital signal processing, the in-air biosonar system on an autocontrolled robot scans water surface with task oriented chirps and sensing strategies. Fishes and motors can be detected and classified in time and frequency domain with a high percentage rate. Experimental result indicates that a mobile robot with in-air biosonar system can achieve the ability of underwater movement detection and classification. However, a precise localization depends heavily on the selection of sensing strategy. [Work supported by NSFC.]

11:15

4aAB9. Water flow detection by larval bullfrogs (*Rana catesbeiana*): Learning and group effects. Sarah A. Stamper and Andrea Megela Simmons (Dept. of Psych., Brown Univ., Providence, RI 02912)

The lateral line system in bullfrog tadpoles (*Rana catesbeiana*) detects water current but mediates orientation away from, rather than toward, the source of current flow. In these experiments, we examined the effects of repeated testing and of group formation on flow detection. Tadpoles (Gosner stages 24–28) were placed in a laminar flow tank in which visual, olfactory, and auditory cues were controlled. Each animal was tested multiple times per day and across multiple days. All animals oriented away from the flow. In addition, the mean latency to adopt a stable position in the tank significantly decreased as a function of repeated testing both within and across days. In a second experiment, animals were tested in groups. Under these conditions, interanimal distances declined significantly at higher flow rates. These experiments suggest that orientation away from water flow in the larval bullfrog may function to facilitate avoidance of current flow produced by approaching predators. In this case, tadpoles should show a preference for locations with reduced water flow and they would benefit from remembering these locations and finding them quickly. Tadpoles would also benefit from forming aggregations in the presence of flow, if potentially generated by a predator, because of dilution effects.

11:30

4aAB10. Sound source localization by the plainfin midshipman fish (*Porichthys notatus*). David Zeddies (Marine Acoust. Inc., 4100 Fairfax Dr., Arlington, VA 22203, davidzeddies@gmail.com), Richard Fay (Loyola Univ. Chicago, Chicago, IL 60626), Peter Alderks, Kiel Shaub, and Joseph Sisneros (Univ. of Washington, Seattle, WA 98195)

Sound source localization of the midshipman fish (*Porichthys notatus*) was studied using the phonotactic response of gravid females to synthetic advertisement calls. Playback experiments were conducted in a 12-ft-diameter outdoor concrete tank at the Bodega Marine Laboratory using a J-9 transducer placed at the center of the tank. The sound field in the tank was measured at 5-cm intervals using an eight-hydrophone array to measure the pressure gradients from which particle motion vectors were calculated. The acoustic measurements confirmed that the J-9 projector was operating as a monopole source. Animals were released 90 cm away from the sound source, and 60 positive phonotactic responses from naïve gravid females were video taped and analyzed. The phonotactic responses consisted primarily of straight to somewhat curved tracks to the sound source. Abrupt changes in trajectory to the sound source were rarely observed. The results confirm that fish can locate sound sources in the near field.

11:45

4aAB11. Recognizing holographic perception. Richard Rikoski (Naval Surface Warfare Ctr., Panama City, 110 Vernon Ave., Panama City, FL 32407)

Recent robotics work has demonstrated that the holographic property of synthetic aperture sonar images can be used to enable object or terrain recognition using real aperture sonars. For instance, it was shown using Gulf of Mexico data from the small synthetic aperture minehunter that terrain can be recognized using as little as a single sonar element and a single ping. Similar capabilities have been ascribed to marine mammals, raising questions about whether the techniques are similar. This paper describes the basics of holographic perception and a series of experiments, which can be used to rule out its use.

Session 4aEA

Engineering Acoustics: Acoustics for Battlefield Operations and Homeland Security II

Michael V. Scanlon, Chair
U. S. Army Research Lab., 2800 Powder Mill Rd., Adelphi, MD 20783-1197

Chair's Introduction—8:00

Contributed Papers

8:05

4aEA1. A biomimetic acoustic system for threat detection and localization. Socrates Deligeorges, Christian Karl, Leah Field, Shuwan Xue, Aaron Soloway, Lee Lichtenstien (BioMimetic Systems, 810 Memorial Dr. Ste. 106, Cambridge, MA 02139), Aleks Zosuls (Boston Univ., Boston, MA 02215), Tyler Gore (BioMimetic Systems, Cambridge, MA 02139), and Allyn Hubbard (Boston Univ., Boston, MA 02215)

As part of our development efforts to transition cutting edge algorithms to practical devices for use in the field, hardware and software systems using the biomimetic approach are being designed for real world battlefield conditions. A new digital system has been developed that not only improves on existing sniper detection and localization technology but also enables many other capabilities useful for enhanced situational awareness. Capabilities include detection of vehicles and personnel sounds such as speech and footsteps. Systems in development include soldier-worn, vehicle-mounted, and robot-mounted systems, as well as unattended ground sensor systems. Our systems can integrate acoustic target data with GPS and other sensor information using simple GUIs. These systems are modular with multiple interface ports for USB, Ethernet, RS-232, and standard audio jacks. As these systems are transitioned to dismounted soldiers, power, weight, and size become the driving factors in design choices. Additional capabilities such as tracking/identifying a variety of acoustics targets, enhancing warfighter hearing, and fusing information with other sensors (for no additional increase in size, power, and weight) can make these acoustics systems an even more valuable asset. Authors associated with BMS may realize financial profit with the success of this work.

8:20

4aEA2. Enhancing the functionality of a biomimetic acoustic direction finding system with back-end algorithms. Yirong Pu (VLSI and Neural Net Systems Lab., Elec. and Comput. Eng. Dept., College of Eng., Boston Univ., Boston, MA 02215, yrpu@bu.edu), Sarah Kelsall, and Allyn Hubbard (Boston Univ., Boston, MA 02215)

Increasing battlefield awareness can improve both the effectiveness and timeliness of response in hostile military situations. The front-end of the existing biomimetic acoustic direction finding system provides the back-end system with spike trains. The back-end algorithms, transportable to FPGA platforms and other general-purpose computers, are tailored to extract specific information for a variety of possible applications. The gunshot classification and localization (C&L) neural network algorithm can recognize and trace supersonic and muzzle-blast acoustic signals in an environment with a minimum SNR value of 1dB and a temporal resolution of 10 s. The C&L algorithm outperforms cross-correlation algorithms in computational efficiency, memory requirements, and noise robustness. Algorithms under development for speech processing are aimed at determining whether speech is present, identifying the speakers' gender and classifying the language spoken. The gender identification algorithm is composed of single pitch-related measures that are weighted based on their estimated performance. Using a variety of speech record lengthens a type I error of 6–16%.

8:35

4aEA3. Propagation of impulsive sound in the nocturnal boundary layer. Roger Waxler, Carrick Talmadge, Xiao Di, and Gilbert Kenneth (NCPA, Univ. of Mississippi, University, MS 38677, rwax@olemiss.edu)

On clear, dry nights a sound channel, the nocturnal duct, forms in the lowest few hundred meters of the atmosphere. Impulsive sound propagating in a nocturnal duct undergoes severe distortion due to multipath effects and dispersion. At long ranges from the source, the signal from a single impulse is received as an extended wave train beginning with a series of distinct arrivals and ending with a low frequency tail. The nature and form of each of the arrivals will be described. The influence of elevated wind jets and the associated convergence zones will be discussed. Possible applications to signature identification and source ranging will be presented.

8:50

4aEA4. Source-height and frequency dependence in sensitivity analysis of near-ground sound propagation. Chris Pettit (Aerosp. Eng. Dept., U.S. Naval Acad., 590 Holloway Rd., M.S. 11-B, Annapolis, MD 21402, pettitcl@usna.edu) and D. Keith Wilson (U.S. Army Cold Regions Res. and Eng. Lab., Hanover, NH 03755)

Computational forecasts of the near-ground sound pressure level (SPL) are key features of proposed frameworks for designing acoustic sensor networks. In many cases the local weather and terrain will not be known precisely enough to justify high confidence in forecasts of the probability of detection. The sensitivity of SPL forecasts to parameter variations therefore must be known in order to assess the probability of detecting acoustic disturbances in poorly characterized environments. To facilitate these assessments, we have expanded a recent framework for full-field sensitivity analysis (FFSA) throughout the parameter space. This new version continues to employ sampling methods, proper orthogonal decomposition, and cluster-weighted models to develop robust surrogate models for sensitivity analysis. Enhancements shown here include (i) locally linear functions in the cluster-weighted models, (ii) analytical differentiation in place of local response surfaces for computing sensitivities, and (iii) estimation of the forecast uncertainty in the sensitivities. These capabilities are used for FFSA of the near-ground SPL due to a harmonic point source operating at several frequencies. The governing parameters and source height are assumed to vary across wide but physically realistic ranges. The dependence of the forecast uncertainty on various factors is examined.

9:05

4aEA5. Acoustic wave characteristics of coarse and fine grain ground, frequency dependence of material properties. Hasson M. Tavossi (Dept. of Phys., Astronomy Geosciences, Valdosta State Univ., 1500 N. Patterson St., Valdosta, GA 31698.)

Acoustic wave propagation in the ground with both coarse and fine grain materials is investigated. The distinction between the coarse and fine grains is made by the value of the wave number kd, where k is inversely proportional to the wave length and d is associated with the grain size. Wave velocity-dispersion and attenuation are studied at low- and high-frequency limits separately, that is, for kd values much greater and much less than 1, as well as for $kd=1$. It can be shown that the frequency dependence of elastic

wave-velocity, dispersion, and attenuation are related not only to the grain-size and the nature of the contact areas, such as roughness and friction, but also these wave characteristics depend on the grain material. It can be shown that the grain material properties, represented by the elastic moduli, are frequency dependent. This frequency dependence of material properties in turn has effects on the ground wave behavior. Experimental and theoretical findings are presented to show these variations with frequency grain size and grain material. Among other applications, these findings on ground material elastic wave properties could be applied to the battlefield operations such as localization of the near surface explosions.

9:20

4aEA6. Improved time reversal focusing in complex media with inverse filter. Thomas Callaghan (Inst. for Computational and Mathematical Eng., Stanford Univ., Durand Bldg., 496 Lomita Mall, Stanford, CA 94305, tscallag@stanford.edu) and George Papanicolaou (Stanford Univ., Stanford, CA 94305)

We analyze the problem of improving time-reversal refocusing in a complex medium through the use of a noninvasive filter. A source at an unknown location emits a pulse, which is recorded by an active set of, possibly distributed, transducers called the focusing array. The goal is to use only the information available at the focusing array to refocus at the source location while minimizing the received energy away from the source. It has been shown that time-reversal in a random medium exhibits superresolution. However, we investigate further improvement of the resolution by first applying an inverse filter. In general, the construction of such a filter requires invasive measurements on a control array in the vicinity of the source, which we assume are not available. The noninvasive inverse filter utilizes only backscattered signals recorded when the focusing array probes the medium. The result is sharp refocusing at the source comparable to the improvement from use of the invasive filter. Possible applications include communications in complex environments where the goal is to send information to a particular location with low probability of intercept. Temporal compression is also important in communications and we investigate the effect of the inverse filter on this as well.

9:35

4aEA7. Comparison of three wind noise reduction strategies. Richard Raspet, Jeremy Webster, and Jiao Yu (Dept. of Phys. and Astronomy and the Natl. Ctr. for Physical Acoust., Univ. of Mississippi, Box 1848, University, MS 38677)

Wind noise is a serious adverse factor in acoustic detection/location systems. Three types of wind noise reduction devices have been used in the past: streamlined probes, spherical wind screens, and surface mounted devices. When these systems are used outdoors near the surface of the ground, the largest contribution to the wind noise is the interaction of the device or surface with the atmospheric turbulence. The goal of our research program is to develop theories to relate measured wind and turbulence properties to the measured wind noise so that wind noise reduction methods can be optimized for any particular application. In this paper we will present measurements of wind noise reduction with devices using the three strategies listed and compare the reduction achieved. Advantages and disadvantages in a variety of applications will be discussed based on the theoretical predictions.

9:50—10:05 Break

10:05

4aEA8. Development of a portable therapeutic ultrasound system for military, medical and research use. George Lewis, Jr and William Olbricht (Dept. of Biomedical Eng., Cornell Univ., 108 Olin Hall, Ithaca, NY 14853, george@cornellbme.com)

In the past two decades therapeutic ultrasound has obtained attention by the medical community as a tool to relieve arthritis, improve rehabilitation, and enhance wound healing processes. In the research realm, therapeutic ultrasound and its effects on tissue properties are currently being studied to great lengths. For example, researchers are assessing the ability of ultrasound for large molecule transdermal drug delivery, in targeted chemotherapy delivery to brain cancer, and cellular gene-transfer applications. Even though many applications of therapeutic ultrasound exist, the basic instrumentation has not changed much in the past 50 years. Here, we present a novel therapeutic ultrasound system we developed in our laboratory that is capable of producing acoustic power outputs well over the therapeutic range (greater than 50 W), lightweight (under 6 lb), portable (a foot print of $4\times6\times2$ in.^{3}), and rechargeable battery powered. The portable therapeutic ultrasound unit has the potential to replace plug-in medical systems and rf amplifiers used in research, both of which are bulky and burdensome. The portable system is capable of between-office and field service on its long lasting internal battery, making it especially useful for military, ambulatory, and house-call medical applications. [This research was supported by the National Science Foundation, National Institutes of Health, and Transducer Engineering Inc.]

10:20

4aEA9. Phased array for acoustic hail and warning. Timothy McDevitt, Timothy Brungart, Andrew Barnard, and David Jenkins (Penn State Univ., Appl. Res. Lab., P.O. Box 30, State College, PA 16804)

Background is given for the need of a high output acoustic hailing device (AHD) for military use. Those detrimental effects, which require high output power of an AHD, such as refraction, absorption, and insertion loss are briefly reviewed along with associated experimental data. The background for intelligibility is touched to address the importance of frequency response. A prototype phased array AHD, THOR, is then described and characterized via experimental results. [Work supported by the DOD.]

10:35

4aEA10. Fabrication and measurement of polypeptide-based piezoelectric composite polymer film. Dawnielle Farrar, James E. West (Dept. of Mater. Sci. and Eng., Johns Hopkins Univ., Baltimore, MD 21218), Ilene J. Busch-Vishniac (Johns Hopkins Univ., Baltimore, MD 21218), and Seungju M. Yu (McMaster Univ., Hamilton, ON L8S 4K1, Canada)

A new class of polymer composite piezoelectric materials based on piezoactive biopolymer, poly(-benzyl,L-glutamate) (PBLG), and a matrix polymer, poly(methylmethacrylate) (PMMA), is presented. The composite polymer offers the possibility of decoupling the electrical and mechanical properties, therefore improving the overall system efficiency. By simultaneously poling and curing (at ambient conditions) PBLG and methylmethacrylate (MMA) mixture solutions, we fabricated a flexible composite film with a significant portion of the PBLG molecules oriented normal to the film surface. This film exhibited moderate piezoelectricity ($d33=20$ pC/N), and its mechanical characteristics were similar to those of low molecular weight PMMA. Present samples are about 40 μm thick with tensile strength of 13 MPa and Young's modules of 450 MPa. The frequency response is ± 3 dB from 0.1 to 7 kHz and at 1 kHz is linear with acceleration more than a 10 dB range.

10:50

4aEA11. Analitical modeling of piezoelectric ceramic transducers based on coupled vibration analysis. S. Boris Aronov (Dept. of Elec. and Comput. Eng., Univ. of Massachusetts Dartmouth, 151 Martine St., Fall River, MA 02723)

The energy method for analyzing piezoelectric ceramic transducers [B. S. Aronov, J. Acoust. Soc. Am. **117**, 210–220 (2005)] is applied to the treatment of transducers with mechanical systems that can be considered as two-dimensional. Analysis is made following the general outline of the theory of coupled vibration in two degree-of-freedom systems and its extension to calculating resonance frequencies of elastic bodies, as suggested by Gibbe and Blechshmidt [Ann. Phys. **18**, 417–485 (1933)]. The approach to the problem is illustrated with examples of piezoelectric rectangular plates, stripes, and thin-walled cylinders at various orientations relative to crystallographic coordinate system. For all of the examples, the resonance frequencies and effective coupling coefficients are presented as functions of the dimensional aspect ratios. Equivalent electromechanical circuits are introduced, which permit calculation of the transducers performance under different acoustical loading conditions. Practical recommendations for improving the electromechanical properties of the transducers by use of appropriate aspect ratios are discussed.

Session 4aED

Education in Acoustics: Hands-on Experiments for High School Students

Uwe J. Hansen, Chair
Indiana State Univ., Dept. of Physics, Terre Haute, IN 47809

Approximately 20 acoustics experiments will be set up, ranging in complexity from simple resonance on a string to ultrasonic levitation. Around 60 students from local area high schools will perform the experiments with the help from ASA scientists and students. Regular ASA conference participants are welcome to the session as long as they do not interfere with student experimentation.

Session 4aNS

Noise, Architectural Acoustics, and ASA Committee on Standards: Workshop on Standardization for Soundscape Techniques: Soundscape and Sound Quality—Measurement and Lexicon

Brigitte Schulte-Fortkamp, Cochair
Technical Univ. Berlin, Inst. of Fluids Mechanics and Eng., Einsteinufer 25, 10587 Berlin, Germany

Bennett M. Brooks, Cochair
Brooks Acoustics Corp., 30 Lafayette Square, Ste. 103, Vernon, CT 06066

Chair's Introduction—9:00

Invited Papers

9:05

4aNS1. Better soundscapes for all workshops on continuing development of soundscape techniques standardization: Workshop introduction. Brigitte Schulte-Fortkamp (TU-Berlin, Inst. of Fluid Mech. and Eng. Acoust., Einsteinufer 25, D-10587 Berlin, Germany) and Bennett Brooks (Brooks Acoust. Corp., Vernon, CT 06066)

The perception of the soundscape can provide comfort, tranquility, and needed information to the person concerned or may be a source of annoyance. The combination of physical acoustical measurements with the scientific evaluation of perceptual responses to environmental sound, known as soundscaping, is an essential method for the assessment and actualization of positive outdoor environments. The characterization of the acoustical environment includes identifying the nature of the sound sources and the reactions of the perceivers. Soundscaping provides for the measurement, analysis, and design of environmental sound by applying the knowledge of both science and community experts. Much fundamental and practical research has been conducted to establish the bases for the soundscape field. In recent sessions and workshops researchers and practitioners have begun to standardize the available soundscape techniques to allow for more comparison of test and survey results and wider application in design. This workshop continues the discussion, evaluation, and standardization of proposed methods and techniques for soundscape analysis and design. The areas of focus will be a catalog of correlations between physical parameters and perceptual responses, the standardization of a terminology lexicon of soundscape descriptors, and the standardization of measurement procedures.

9:30

4aNS2. Experiments to develop soundscape design methods. Gary Siebein (School of Architecture, Univ. of Florida, P.O. Box 115702, Gainesville, FL 32611-5702, gsiebein@siebeinacoustic.com), Joshua Fisher, Adam Bettcher, Threcia Robinson, Robert Lilkendey, Hyun Paek, Chris Jones, and Reece Skelton (Siebein Assoc., Inc., Gainesville, FL 32607)

A proposed soundscape design method to evaluate acoustical impacts of planning and building projects on the surrounding community as a way to work toward net zero noise impacts is summarized. The concept of net zero impacts is borrowed from ecological planning where buildings are designed to produce as much energy as they use. The idea of a net zero noise impact is one where a building or planning project does not increase the existing ambient noise level during its use. The first step in this process is to define the nature of the existing ambient soundscape in the vicinity of the project. The method includes long term acoustical measurements of ambient sounds, short term detailed measurements of specific acoustic events, focus group meetings with residents and stakeholders to identify and evaluate acoustical issues, methods to map qualitative aspects of the soundscape, computer modeling of various types to

assist in developing design alternatives, evaluation of possible weather effects, qualitative and quantitative assessments of calibrated aural simulations of design alternatives, and postconstruction verification methods. Examples from multiple case studies of large scale infrastructure and building projects are used to document strengths and weaknesses of the proposed method.

9:55

4aNS3. Soundscape standardization of measurement procedures. André Fiebig (HEAD acoustics GmbH, Ebertstrasse 30a, 52134 Herzogenrath, Germany, andre.fiebig.head@head-acoustics.de)

A wide range of measurement systems, questioning techniques, and analysis methods were already applied in previous soundscape studies over the past decades, but a common consent about meaningful procedures and required measurement systems is missing so far. However, a standardization of measurement procedures with respect to a uniform investigation, documentation, and description of soundscapes is required to allow for the valid comparison and analysis of different studies. Up to now, the diversity of used measurement procedures and technologies hinders the in depth derivation of cross-cultural similarities and dissimilarities in the physics of soundscapes and in the perception and assessment of soundscapes. In this paper, an overview of applied measurement technologies and procedures will be given as well as advantages and disadvantages discussed concerning the main questions: (1) how, (2) where, (3) when, and (4) how long must be measured. An initial step in the direction of a common basis of measurement procedures available for soundscape researchers was taken on the occasion of the workshop in Salt Lake City, 2007. This process must be continued. It will promote new ideas in the field of environmental noise research and enhance the acceptance of soundscape concepts in noise policy.

10:20—2:00

Working Groups, Part 1

Working groups will be organized around the following areas of interest, as expressed by persons responding to the workshop announcement or at meeting registration. Working groups will develop presentations on problems, solutions and recommended actions.

To further develop and refine the methods of soundscaping the following are needed:

Working Group A—Catalog of correlations between physical parameters and perceptual responses
Working Group B—Standardization of a terminology lexicon of soundscape descriptors
Working Group C—Standardization of measurement procedures

Working Groups, Part 2

Working group discussions will continue, focusing on (1) what has been done in the past, (2) what should be done now, and (3) how may this be accomplished? There may be some realignment of the participants in the groups.

Luncheon

Working Groups, Part 3

The combination of physical acoustical measurements with scientific evaluation of perceptual responses to environmental sound, known as soundscaping, is an essential method for the assessment and actualization of positive outdoor environments.

Final Group Presentation

The final plenary session of the Workshop will include presentations by the moderators/recorders of all the working groups on their findings. Discussion will include proposed methods, means and possible venues for follow-up and further action. The final set of recommendations will be published and distributed to all of the participants.

Session 4aSA

Structural Acoustics and Vibration: Causality in Acoustics

J. Gregory McDaniel, Chair
Boston Univ., Aerospace and Mechanical Eng., 110 Cummington St., Boston, MA 02215

Invited Papers

8:30

4aSA1. Causality and mathematical models in vibration and acoustics: A realistic perspective. Allan D. Pierce (Dept. of Mech. Engrg., Boston Univ., Boston, MA 02215, adp@bu.edu)

Acoustic and vibrations applications require stricter causality conceptions than primitive causality (effect never precedes cause). Relativistic causality (nothing travels faster than light) is irrelevant; there is no practical reason that a satisfactory continuum-mechanical model, holding for low to moderate frequencies, be relativistically invariant. Modifying the requirement so that the speed of light is replaced by some acoustic speed is not satisfactory, as the insertion of dissipative mechanisms into any continuum-mechanical model invariably results in small precursors which may precede sonic-velocity wavefronts. These are small, but they are formally nonzero at arbitrarily large distances in advance of the front. The present paper follows Ginzberg (1955) and advocates acoustic causality: the requirements that (i) the precursors die out rapidly with distance, (ii) up to some frequency of interest acoustic disturbances genuinely propagate, with the attenuation per wavelength being substantially less than unity, and (iii) vibrations and propagation are governed by coupled partial differential equations. With these principles as a guide, approximate relations involving extrapolations into the complex plane are derived, and it is shown how error bounds can be placed on applications of various members of a derived family of Kramers–Kronig relations. Very low-frequency relaxation processes account for proportional damping in vibrations.

9:00

4aSA2. Implications of causality on acoustic propagation in highly dispersive bubbly media. Gregory Orris, Dalcio Dacol, and Michael Nicholas (Naval Res. Lab., 4555 Overlook Ave., SW, Washington, DC 20375)

Causality in nearly all physical systems has been a recurrent subject often causing apparent paradoxes since before the 20th century. Linear acoustic propagation through subsurface bubble clouds in the ocean offers an especially challenging physical system within which to investigate issues of causality, and has in the past had several competing fundamental theories. Signal travel times and absorption in such a system exhibit enormous variations depending on the acoustic signal frequency, bubble size distribution, void fraction, and other ambient physical parameters. In a recent work [Orris *et al.*, J. Acoust. Soc. Am. **121**, 3349–3362 (2007)] we presented a correction to some contemporary theories of acoustic propagation in bubbly media to bring them into compliance with the physical law of causality. We will discuss this theory within the context of complex analysis and some of its implications to acoustic signal propagation; also present experimental data, which commensurate with archival data, suggest that the theories are still far from offering a complete description of the physical phenomena surrounding acoustic propagation in bubbly media. Possible modifications will be explored that may lead to a complete self-consistent causal theory of acoustic signal propagation in bubbly liquids. [Work supported by the Office of Naval Research.]

9:30

4aSA3. Implicitly Causal Expansions in the Frequency Domain. J. Gregory McDaniel (Mech. Eng. Dept., 110 Cummington St., Boston, MA 02215)

While the causality statement in the time domain is quite simple, the corresponding statement in the frequency domain involves Hilbert transform relations between the real and imaginary parts of the relevant transfer function. If the transfer function is minimum phase, one can go further and develop Hilbert transform relations between the amplitude and phase. Such relations are important and useful in at least two classes of problems: analysis of frequency-sweep data and active control. In both problems, one usually wishes to simultaneously enforce the causality statement while achieving some other goals. This lecture will explore various ways of accomplishing this and will focus on implicitly causal expansions of transfer functions in the frequency domain. The expansion functions are built directly from Hilbert transform pairs and therefore the series is guaranteed to be causal. One example is a complex Fourier series in frequency in which the coefficients are required to be real valued. Examples will be developed in which the causal series expansions are used to improve the quality of data, by eliminating noncausal noise and to achieve active control. [This work was supported by the Office of Naval Research under Grant N00014-99-1-1017.]

10:00—10:15 Break

10:15

4aSA4. Acoustic Kramers–Kronig relations in the ultrasonic frequency band. Joel Mobley (NCPA, Univ. of Mississippi, 1 Coliseum Dr., University, MS 38677)

Physical manifestations of the principle of causality, Kramers–Kronig (KK) relations, have proven to be adaptable to a wide array of tasks which include measuring fundamental material parameters, establishing the consistency of laboratory data, and building causally consistent physical models. This talk is concerned with the use of finite bandwidth KK relations between and among the components and derivatives of the complex wavenumber in the low megahertz ultrasound band. Special focus is given to their applicability to data from suspensions of resonant scatterers and media exhibiting attenuation with a power-law dependence on frequency. One recent development is the validation of a KK relation for the direct prediction of the group velocity from the attenuation coefficient, which has demonstrated great utility for suspensions with resonant type dispersion. The roles of KK analysis in other recent issues are also discussed, including the apparent negative dispersion in cancellous bone.

10:45

4aSA5. Is an impedance operator necessary causal, and is this an issue of complexity? John J. McCoy (School of Eng., The Catholic Univ. of America, Washington, DC 20064)

An impedance operator describes the mapping of a velocity field across a part of a boundary surface, to the traction field across the same part. Understood to represent the solution of a "direct" problem, i.e., the velocity field describes the problem forcing and the traction field part of the solution, the impedance operator is necessary causal. On the other hand, understood to represent the general solution of an "inverse" problem, i.e., the velocity field is part of the observed solution with the traction field representing the problem forcing, the operator need not be causal. Continuing, a uniqueness theorem that applies to the direct problem assures that the impedance operator thusly defined is unique. The lack of a corresponding theorem for the inverse problem suggests that the impedance operator thusly defined need not be unique. This further suggests requiring causality selects from *multiple* impedance operators, representing multiple solutions to the inverse problem, the one that is unique. This raises two questions. Is the causality that makes the operator unique a requirement of the governing physics? What impact does this have on the concept of impedance as a tool for addressing complexity in dynamical systems?

THURSDAY MORNING, 13 NOVEMBER 2008 LEGENDS 7, 9:00 A.M. TO 12:00 NOON

Session 4aSC

Speech Communication: Production (Poster Session)

Ewa Jacewicz, Chair
Ohio State Univ., Speech and Hearing Sci., 1070 Carmack Rd., Columbus, OH 43210

Contributed Papers

All posters will be on display from 9:00 a.m. to 12:00 noon. To allow contributors an opportunity to see other posters, contributors of odd-numbered papers will be at their posters from 9:00 a.m. to 10:30 a.m. and contributors of even-numbers papers will be at their posters from 10:30 a.m. to 12:00 noon.

4aSC1. Development of temporal characteristics in the speech of hearing impaired preschoolers. Mark VanDam, Nicholas A. Smith, Dana Ide Helvie, and Mary Pat Moeller (Boys Town Natl. Res. Hospital, 555 N 30 St, Omaha, NE 68131, vandamm@boystown.org)

This longitudinal study examined the development of temporal speech properties in hearing impaired and normal hearing children at 4 and 5 years of age. Children repeated a list of target words following the experimenter's model. Measures of duration for onset, nucleus, coda, and syllable were collected for children with normal hearing and children identified early (mean = 3 months) versus late (mean = 30 months) as hearing impaired. Main effects of age and group were observed for nucleus, coda, and syllable but not onset duration. Early-identified children were more similar to normal-hearing children than late-identified peers, despite early-identified children having much less hearing (mean diff. = 40 dB HL). Age and group differences were examined using (1) relationships among acoustic duration measures, (2) phone-by-position accuracy, and (3) spoken word intelligibility to assess the influence of hearing experience on development. Although there was a wide individual variation, results suggest benefits of early identification: early identified hearing impaired children performed more like normal hearing children. Results favor a "delayed-acquisition" over "different-mechanism" model for the development of temporal speech properties in children with hearing loss. [Work supported by NIH-NIDCD T32 DC00013-26; R01 DC006681; and P30 DC04662.]

4aSC2. Children's articulatory constraints inferred from acoustic output: How some speech-sound errors arise. Richard S. McGowan (CReSS LLC, 1 Seaborn Pl., Lexington, MA 02420) and Susan Nittrouer (The Ohio State Univ., Columbus, OH)

Our investigations of children's speech acoustics indicate that normally developing children exhibit speech behavior that is not simply scaled adult behavior. Specific anatomical differences between children's and adults' vocal tracts cause these effects: For example, the size of the tongue in relation to the size of mouth decreases with age. The effects of these age-related anatomical differences have been identified for preschool children as young as 1 year of age in phonetic segments, such as /ɹ/, /s/, and /ʃ/. These anatomic differences may lead children to produce subphonemic distinctions, as between /r/ and /w/ in English. Children's anatomical features can also affect sounds generally not considered to be difficult for normally developing children to produce, such as syllable-initial stops. We have noted children 12–18 months old producing intended /g/ that is often transcribed as /d/ by adult listeners. However, fronted velar /g/, which could be the result of a large

tongue size in relation to palate size, exhibits subphonemic distinctions with children's /d/. The behaviors arising from early anatomical features can be preserved into school age and be labeled as aberrant articulation.

4aSC3. Developmental study of the relationship between F0 and formant frequencies. Peter F. Assmann (Univ. of Texas at Dallas, Richardson, TX 75083), Terrance M. Nearey (Univ. of Alberta, Edmonton, AB T6G 2E7, Canada), Sneha V. Bharadwaj, Daniel Hubbard, and Anu Jayaraman (Univ. of Texas at Dallas, Richardson, TX 75083)

There is a systematic relationship between fundamental frequency (F0) and formant frequencies in natural speech across adult talkers, associated with anatomical differences in the length of the vocal tract and vocal folds. In the present study we examined developmental trends in this relationship using a database of vowel recordings from adults and children ranging from 5 to 18 years of age from the Dallas, Texas region. A moderate correlation was found between the geometric mean of the formant frequencies (F1–F3) across all of the vowels for a given speaker (a measure related to vocal tract length) and the geometric mean F0. Overall the correlation was higher in males (r=0.87) than in females (r=0.46) and increased as a function of age. The presence of systematic covariation between F0 and formant frequencies is consistent with studies showing a perceptual contribution of F0 to vowel identification.

4aSC4. Formant lowering in spontaneous crying speech. Donna Erickson (Showa Music Univ., 1-11-1 Kamiaso, Asaoku, Kawasaki 215-8558, Japan, ericksondonna2000@gmail.com), Takaaki Shochi (Gipsa-Labs, Grenoble, France), Hideki Kawahara (Wakayama Univ., Wakayama 640-8510, Japan), Albert Rilliard (LIMSI-CNRS, France), and Caroline Menezes (Univ. of Toledo, Toledo, OH)

Acoustic and articulatory recordings were made at the EMA facilities of NTT Research Laboratories, Atsugi, Japan, for an American English speaker producing (a) spontaneous crying speech and (b) imitation of phrasing of the original crying speech, as control data. Articulatory analysis indicates differences in jaw, lip, and tongue positions for crying speech versus control speech. Acoustic analysis also shows that for crying speech compared with control speech, not only *F*0 increases but also higher formants tend to be lowered. Results of perception tests using the copy-synthesis program STRAIGHT (Kawahara) to morph a continuum of stimuli, keeping *F*0, duration, and intensity constant, suggest listeners to use cues of lowered formants to perceive emotional intensity of an utterance. Recent biophysiological modeling studies suggest that lowered formants may be due to a lowered larynx along with an expanded hypopharyngeal region [e.g., D. Honda, J. Acoust. Soc. Am. (1966); Kitamura *et al.*, Acoust. Sci. Tech. (2004)]. This hypothesis as it applies to crying speech is currently being explored. [This work was supported in part by Japanese Ministry of Education, Science, Sport, and Culture, Grant-in-Aid for Scientific Research (C), (2007–2010): 19520371 and SCOPE (071705001) of Ministry of Internal Affairs and Communications (MIC), Japan.]

4aSC5. Cross-linguistic acquisition of vowels: English, Korean, Greek, and Cantonese. Hyunju Chung, Jan Edwards, and Gary Weismer (Dept. of Communicative Disord., Univ. of Wisconsin-Madison, Goodnight Hall 1975 Willow Dr., Madison, WI, 53706, hchung23@wisc.edu)

It has been widely claimed that vowels are acquired earlier than consonants. This is why relatively few studies have focused on investigating acquisition patterns of vowels. However, the acquisition patterns of consonants are not separable from those of vowels and a few studies [e.g., work of MacNeilage (1990)] suggest that vowel acquisition is more complicated than previously assumed. Furthermore, there is relatively little cross-linguistic research on how children master language-specific characteristics of vowels. While children show preferences for native-language vowels by 6 months of age, language-specific patterns in production emerge considerably later. This study examines cross-linguistic variation in the location of shared vowels in the vowel space across four languages: English, Korean, Greek, and Cantonese for 2-year-old, 5-year-old, and adults. The vowels /i/, /u/, and /a/ were elicited in familiar words using a word repetition task. Productions of target words were recorded and transcribed by native speakers of each language. First and second formant frequencies were measured for correctly produced vowels. Language-specific differences in the location of shared vowels were observed in the formant values of both children and adults. [This work was supported by a Fulbright Fellowship to H.C., and NIDCD Grant 02932 and NSF Grant 0729140 to J.E.]

4aSC6. Psychoacoustic measures of stop production in Cantonese, Greek, English, Japanese, and Korean. Timothy Arbisi-Kelm (Dept. of Communicative Disord., Univ. of Wisconsin-Madison, 1975 Willow Dr. Madison, WI 53706, arbisikelm@wisc.edu), Mary Beckman, Eunjong Kong (The Ohio State Univ., Columbus, OH 43210), and Jan Edwards (Univ. of Wisconsin-Madison, Madison, WI 53706)

Spectral analyses of stop bursts have revealed that the place of articulation can be predicted based on both invariant and time-varying cues present within the acoustic signal (e.g., Stevens and Blumstein, 1978; Forrest *et al.*, 1988). While prior studies have had some success in uncovering such cues for American English, it is not clear whether these parameters are equally pertinent in stoping consonant classification in other languages. Furthermore, one of the main limitations of a linear acoustic analysis is that it imposes different scales of loudness and frequency on the acoustic signal than does the human ear, thus generating power spectra with different frequency distributions than are produced by the auditory system (e.g., Zwicker 1961; Kewley-Port, 1983). In the present study of word-initial stops produced in Cantonese, English, Greek, Japanese, and Korean, measures derived from a psychoacoustic model of auditory perception were developed in order to more accurately isolate the front cavity resonances of the burst transient. For all languages, peak amplitude frequency and a peak compactness measure successfully distinguished alveolar from velar stops with at least 74% accuracy and were more accurate at stop classification than were spectral moments measures.

4aSC7. The effect of secondary labialization on stop burst spectra. Yunju Suh (Dept. of Linguist., Stony Brook Univ., Stony Brook, NY 11794, yunjusuh@gmail.com)

Secondary labialization increases the size of the cavity before /t/ and /k/ constrictions, rendering their burst spectral energy concentrated in the lower-frequency region than when they are not labialized. However, the peak location and center of gravity of the Spanish and the Korean stop burst spectra before /(w)e/ and /(w)a/ only captured the frequency lowering effect of labialization on /k/ bursts and failed to distinguish between the plain and labialized /t/ bursts. Spectral shapes of both /t/ and /k/ bursts were altered by /w/ but in different ways: The single prominent peak of the compact /k/ burst spectra was located in significantly lower frequency when it co-occurred with /w/, whereas the two prominent peak locations did not differ between the plain and labialized /t/ burst spectra. What differentiated /tw/ from /t/ instead were the nonexistence of the high-frequency peaks (above 4 kHz) and the amplitude increase of the peak around 3 kHz in /tw/. As a result, /tw/ burst had spectral energy concentrated below 4 kHz, unlike diffuse /t/ spectra whose energy was spread over a wider frequency range. The amplitude ratio between the mid-, and high-frequency regions (A_{mid}-A_{hi}) successfully captured this difference between the plain and labialized coronal stop bursts of both Korean and Spanish.

4aSC8. Voice onset time of Korean stops as a function of speaking rate. Eunjin Oh (Dept. of English Lang. and Lit., Ewha Womans Univ., Seoul 120-750, Korea, ejoh@ewha.ac.kr)

This study aimed to explore the effects of varying speaking rate on voice onset time (VOT) of stops in Korean and to see whether contrasts among stop categories are maintained despite these variations. Plain, tense, and aspirated stops in /CVn/ words (C = three stop places, V = three vowels) in a carrier phrase were examined at both normal and fast rates, which were controlled by alternating phrases on a computer screen at intervals of 2 s and 1 s, respectively. Results revealed that plain and aspirated stops moved toward smaller VOT values, while tense stops did not significantly change as a function of rate. These results are in accordance with Kessinger and Blumstein [J. Phonetics **25**, 143–168 (1997)], who found that long-lag and prevoiced categories shifted toward short-lag values at a fast rate in Thai, French, and English. Overlap in VOT ranges between plain and aspirated stops often occurred even at the normal rate, although the degree of overlap was larger at the fast rate, indicating that phonetic cues other than VOTs

play a critical role in characterizing the stop categories in Korean. However, VOTs of tense and plain stops generally did not overlap under either rate condition.

4aSC9. Acoustic features of American-English vowels for English, Chinese, and Korean talkers. Chang Liu and Sangeeta Kamdar (Dept. of Commun. Sci. and Disord., Univ. of Texas, 1 University Station, A1100, Austin, TX 78712)

Sixteen American-English vowels including 12 monothongs and 4 diphthongs were recorded in a phonetic context of /hvd/ from young English, Chinese, and Korean talkers. The Chinese and Korean talkers were bilingual and had stayed in US from 6 months to 6 years. Results of acoustic analysis showed that there was no significant difference in F1×F2 vowel space among the three groups of talkers. In addition, the three groups of talkers showed great similarity in F2/F1 ratio across the 12 monothongs. Vowel durations had significantly greater variability across vowel categories for the Chinese and Korean talkers than for the English talkers, indicating that, besides producing spectral differences among vowels, Chinese and Korean talkers also attempted to generate durational difference among vowels to make each vowel distinguishable from others. More acoustic features such as spectral tilt and formant transition in the diphthongs will be discussed as well as the effects of the second language experience.

4aSC10. Acoustics of epenthetic vowels in Korean loanwords. Hyun-ju Kim (Dept. of Linguist., Stony Brook Univ. (SUNY), S205 SBS, Stony Brook, NY 11794-4376, hyunjkim@ic.sunysb.edu)

Several previous studies reported that epenthetic vowels in other languages were phonetically not the same as lexical vowels: for example, English speakers produce inserted schwas as transitional, which are shorter in duration and lower in *F*1 than lexical schwas [L. Davidson, J. Phonetics **34**, 104–137 (2006)]. This study examines whether Korean epenthetic vowels in the production of non-native phonotactics are real vowels or are transitional elements that appear due to failure to coordinate the two consonant gestures. In the experiment, Korean speakers were asked to produce illegal consonant clusters contained in pseudowords written in English and the same consonants but with an intervening lexical vowel in native words written in Korean. Results showed that epenthetic vowels were not different phonetically (in duration, *F*1, and *F*2) from lexical vowels in native words, which is different from what the previous study of epenthetic vowels in English found. Given the fact that complex codas are never possible in Korean phonology, whereas certain types of complex codas are permissible in English, this finding suggests that distinct native phonology may generate language-specific phonetics and force Korean speakers to produce epenthetic vowels as real.

4aSC11. Phonetic status of Cj combinations in Korean and Spanish. Young-ran An, Jiwon Hwang, and Yunju Suh (Dept. of Linguist., Stony Brook Univ., Stony Brook, NY 11794-4376)

Korean allows combinations of consonant and glide (CG) at onset position but forbids obstruent+liquid (OL) clusters. This is a potential problem for the universal sonority dispersion principle, which can be avoided if the Korean CG combinations are secondary-articulated consonants rather than clusters. To see if this hypothesis is phonetically supported, we compared Korean with Spanish, which allows both CG and OL onsets. *F*2 at the vocoid onset of (C)jV syllables varied as a function of the backness of the following vowel in Korean, whereas it stayed constant in Spanish. The vocoid duration increase from CV to (C)jV was also smaller in Korean. This shows that the Korean /j/ is weak in that it lacks a target frequency and its tongue position is decided by the following vowel. However, this property is not confined to the Cj combination, as CjV and jV syllables behaved in the same way. Our results thus support the idea that the Korean CG is close to secondary-articulated consonants, but the weak realization of /j/ is not a contextual variation after a consonant. One possible explanation for this pattern may come from the inherent property of CV coarticulation in Korean.

4aSC12. The influence of different tones of Mandarin Chinese on the temporal characteristics of nasalization. Wenlang Zhang and David Kuehn (Dept. of Speech and Hearing Sci., Univ. of Illinois at Urbana-Champaign, 901 South Sixth St., Champaign, 61820, wzhang26@uiuc.edu)

This study was designed to investigate whether the four different tones in Mandarin Chinese would influence the temporal characteristics of nasalization. Seven female and seven male subjects were enrolled in this study. Four nasal syllables/ma mi na ni/ in all four tones were embedded in two syllables with initial pressure consonants to form the stimuli. Then the nasal onset intervals, nasal consonant durations, nasal offset intervals, and the whole nasalization durations were segmented in the speech samples. The corresponding durations and ratios for the same syllable were compared pairwisely among the four tones by paired means *t*-test. Multiple statistically significant differences did exist among the four tones in both the durations and the ratios. The most important differences were as follows: Tone 3 has shorter nasal consonant durations than Tones 1 and 4, and shortest nasal offset intervals and whole nasalization durations among the four tones; it also has a larger nasal onset and nasal consonant duration ratios but least nasal offset ratios among all four tones. Different tones of Mandarin Chinese can influence the temporal characteristics of nasalization, and they may serve as extra cues that can help improve perception.

4aSC13. Palatalization in Romanian: Acoustics, perception, and the role of place of articulation. Laura Spinu, Irene Vogel (Dept. of Linguist. and Cognit. Sci., Univ. of Delaware, 46 E Delaware Ave., Newark, DE 19711), and Timothy Bunnell (Nemours Biomedical Res., Wilmington, DE 19803)

Departing from the crosslinguistic generalization whereby the contrast between the plain and palatalized consonants is favored at the coronal, as compared to the labial, place of articulation, recent perceptual studies show native speakers of Romanian displaying higher sensitivity to this contrast in labials. To investigate this unexpected behavior, a production study was conducted with 31 subjects. Five plain and palatalized fricatives (/f, v, z, S, h/) were analyzed in terms of average duration and spectral properties (coefficients of the Bark Cepstrum). A linear discriminant analysis was run using duration and the Cepstral coefficients to predict segment type (plain/palatalized). 78.2% of 3674 tokens were classified correctly; however, the contribution of the duration and spectral properties of each segment showed interesting asymmetries. To summarize, /h/ was most successfully distinguished, /S/ was least successfully distinguished, and /f/ and /v/ were distinguished better than /z/. Our acoustic analysis supports the perceptual findings regarding palatalization in Romanian. Perceptually, the distinction between the plain and palatalized consonants was strongest with labials. This is paralleled by the greater acoustic difference between the plain and palatalized /v/, /f/ versus /z/, /S/. Thus, Romanian exhibits palatalization patterns that appear at odds with the claim that the least marked place is coronal.

4aSC14. Acoustic properties of clear speech in dysarthria. Kris Tjaden, Joan Sussman, Erin Szjata, Grace Liu, Katrina Fulcher, Beth Hilczmayer, Miranda Crumb, and Ken Johnson (Dept. of Communicative Disord. and Sci., Univ. at Buffalo, 3435 Main St., 122 Cary Hall, Buffalo, NY 14214, tjaden@buffalo.edu)

Clear speech produced by neurologically normal speakers has been shown to be more intelligible than conversational or habitual speech, although the magnitude of the effect varies widely among speakers. Speech production strategies underlying the improved intelligibility associated with clear speech have also been described in a number of acoustic studies. Although clear speech effects would be of interest in speech disorders such as dysarthria, where habitual intelligibility may be compromised, few dysarthia studies have examined clear speech [see A. Goberman and L. W. Elmer, J. Comm. Disord. **38**, 215–230(2005)]. The current study reports acoustic characteristics of clear speech for individuals with dysarthria secondary to multiple sclerosis and idiopathic Parkinson's disease. A group of healthy control speakers was studied for comparison purposes. As part of a larger study, all speakers produced a list of 25 Harvard sentences in habitual and

clear speaking conditions. Both segmental and suprasegmental acoustic measures will be reported. Group effects as well as individual speaker trends will be examined. [Work supported by NIH]

4aSC15. Acoustic characteristics of Lombard speech in Parkinson's disease patients. Firas Al-Fwaress, Suzanne Boyce (Dept. of Commun. Sci. and Disord., Univ. of Cincinnati, 3202 Eden Ave., Cincinnati, OH 45267-0379, boycese@email.uc.edu), Kathy Groves-Wright (Cincinnati Veterans Medical Ctr., Cincinnati, OH 45220), Jean Neils-Strunjas (Univ. of Cincinnati, Cincinnati, OH 45267-0379), and Angel Ball (Texas A & M Univ.-Kingville, Kingsville, TX 78363)

Lombard speech refers to the well-known effect by which speakers talk differently in a noisy environment than they would in a quiet environment. This difference involves both increased loudness and acoustic phonetic characteristics that enhance intelligibility. Parkinson's disease (PD) patients who show reduced intelligibility of speech have also been shown to exhibit impaired sensory integration of auditory feedback [Kiran Larsen, JSLHR, 2001]. In this paper, we examine the Lombard effect on speech in noise by PD patients and healthy age-matched controls. The results of acoustic phonetic measures suggest that the Lombard speech behavior of PD patients without dysarthria resembles that of control subjects both in quiet and in noise. However, patients with mild-to-moderate dysarthria show fewer effects of Lombard speech, suggesting that their ability to adjust the intelligibility of their speech in noise is correlated with their level of dysarthria.

4aSC16. Consonant-vowel and diphthong transitions in the speech of persons with dysarthria and of healthy controls. Christina Kuo and Gary Weismer (Dept. of Communicative Disord., Univ. of Wisconsin-Madison, 1975 Willow Dr., Madison, WI 53706 and Waisman Ctr., 1500 Highland Ave., Madison, WI 53705, kuo2@wisc.edu)

Formant transitions have been of interest to researchers for their contribution to speech perception, sound identification, and inferences to articulatory behavior. In previous work diphthong transitions have been shown to be sensitive to speech motor control deficits found in dysarthria; comparable data regarding transitions between obstruents (i.e., consonants) and vowels are not available. Here consonant-vowel (CV) and diphthong transitions in speakers with dysarthria and in healthy controls are examined to understand whether the effects for diphthong transitions observed in speakers with dysarthria—reduced extent and slope and occasionally lengthened duration—are present for CV transitions. The first part of this study extends work by Weismer *et al.* [J. Acoust. Soc. Am. **121**, 3135 (2007)], who reported a tendency for shallower CV transitions in speakers with dysarthria when compared to healthy controls, but only for syllables where C=dorsal. Given the limited number of dorsal CV transitions in the previous work, more utterances are included to better balance the sample sizes for different places of articulation (i.e., bilabial, alveolar, and dorsal) and also between the two speaker groups. Distributional analyses for several transition measures will be presented for 8 speakers with dysarthria and 18 healthy controls. [Work supported by NIDCD R01 DC003723.]

4aSC17. Acoustic variability and speaker discriminative power of liquids in American English. Xinhui Zhou, Daniel Garcia-Romero, and Carol Espy-Wilson (Elec. and Comput. Eng. Dep., Univ. of Maryland, College Park, MD 20740)

In American English, liquid sounds /r/ and /l/ are the most articulatorily variable and complex sounds. In previous work [Zhou *et al.*, J. Acoust. Soc. Am. **123**, pp. 4466–4481 (2008)], we found that the acoustic variability of /r/ due to two different tongue shapes ("retroflex" versus "bunched") is reflected at the fourth and fifth formants. In order to understand how this articulatory diversity contributes to the intra- and interspeaker variabilities in speech signals of liquid sounds, an analysis of variance (ANOVA) analysis has been performed to investigate the intra- and interspeaker variabilities of liquid sounds across different frequency subbands. The Buckeye database was analyzed in this study, which includes about 30–60 min of broadband conversation speech for each of 40 speakers. The ANOVA analysis showed that liquids have the maximum F-ratios (interspeaker variance/intraspeaker variance) in the range of about 3–5 kHz, and /l/ has a larger maximum F-ratio than /r/. In general, liquids have larger F-ratios than stops and fricatives and have smaller F-ratios than vowels and nasals. The results of phoneme-based speaker identification task will be presented to show the speaker discriminative power of liquids along with the results for other phonemes such as vowels and nasals.

4aSC18. On the relation between locus equations and subglottal resonances. Steven M. Lulich (Speech Commun. Group, MIT, 77 Massachusetts Ave., Rm. 36-595, Cambridge, MA 02139, lulich@speech.mit.edu)

In consonant-vowel transitions, it is well known that the frequency of the second formant at the onset of voicing ($F2_{\text{onset}}$) is linearly correlated with the frequency of the second formant in the middle of the vowel ($F2_{\text{vowel}}$). This correlation, which holds across the vowel contexts for a given consonant place of articulation (POA), is characterized by a regression line (locus equation) with a slope and y-intercept that depend on the consonant POA. Furthermore, for a given POA, slopes and y-intercepts of collections of locus equations are inversely related. The cause of this inverse relation has not yet been explained. In this presentation, we will show that the inverse relation implies that the $F2_{\text{vowel}}$ vs. $F2_{\text{onset}}$ coordinate system is most naturally described as a mathematical translation away from the origin, and that the size of the translation is a function of the POA and of the second and third subglottal resonances.

4aSC19. Does vowel inventory or inventory size condition the articulation of /i/ and /y/? Michel T.-T. Jackson and Richard S. McGowan (CReSS LLC, 1 Seaborn Pl., Lexington, MA 02420)

Wood [J. Acoust. Soc. Am. **80**, 391–401 (1986)] and dispersion-focalization theory (DFT) [Schwartz *et al.*, J. Phonetics **25**, 255–86 (1997)] have made differing predictions about variation in the articulation of /i/ and /y/. Wood claimed that there are "language-specific tendencies to either prepalatal or midpalatal tongue positions for palatal vowels … languages contrasting [i] with [y] preferring the prepalatal position for both vowels" [Wood (1986), p. 392]. However, DFT predicts that the high-front vowel /i/ is always driven to near the high-front corner of the acoustic space in order to maximize perceptual-acoustic distinctness from the rest of the vowels in the inventory of the language. In addition, it is possible that languages with smaller vowel inventories have less extreme articulations for "corner" vowels such as /i/ and /y/ overall. In this study, we compare articulatory measures of constriction location, extent, and degree in four languages (with /y/ versus without /y/ and small inventory versus large inventory).

4aSC20. Final consonant voicing and vowel height contrasts in whispered speech. Yana Gilichinskaya and Winifred Strange (Univ. of New York-Grad. Ctr., 365 Fifth Ave., New York, NY 10016-4309, ygilichin-skaya@gc.cuny.edu)

Whispered speech is a naturally distorted speech signal. Whereas it preserves some characteristics of fully phonated speech, some important acoustic cues are removed, diminished, or altered. The prominence of acoustic cues in whispered speech may change due to the physical properties of the whispered speech signal, i.e., decreased intensity, the absence of periodic vibration of the vocal folds, damping of $F1$, shift of the formants, and flattening of the amplitude envelope. Such changes affect the acoustic cues both for vowels (e.g., vowel height) and consonants (e.g., voicing contrasts). The objective of the present project was to explore the acoustic cues for post-stressed syllable-final consonant voicing contrasts and the vowels preceding them in continuous whispered speech of American English speakers and to compare the results with those in fully phonated speech. The stimuli were recorded in the carrier sentence "I'll utter /habVC/ off the list." The consonant pairs included voiced/voiceless bilabial stops /b-p/ and labiodental fricatives /f-v/, each combined with 11 AE vowels /i, ɛe, æa, ʌo, ɔu/. Preliminary results showed that vowels had longer duration in whispered speech than in fully phonated speech. Spectral dispersion, temporal contrastiveness of vowels, $F1$, and vowel duration cues will be reported in the presentation.

4aSC21. Acoustic characteristics of sonorant consonants. Phoebe Allen, Marios Fourakis, and Gary Weismer (Dept. of Communicative Disord., Univ. of Wisconsin-Madison, 1975 Willow Dr., Madison, WI 53706)

This is a report on the acoustic characteristics of sonorant consonants in Midwestern American English. Ten speakers (five male and five female) of south central Wisconsin origin were recorded producing these consonants. The sonorants [l,r,m,n] plus the velar nasal, when possible, were elicited in the word initial, medial, and final positions. In the initial and final positions,

the immediately adjacent vowel varied over three different stressed vowels. In the final position, the sonorants also occurred postconsonantally, as in the word bottom resulting in their syllabic versions. All but 4 of the 37 words used were real words. Five repetitions of each word were recorded. Measurements of durations, amplitudes relative to the adjacent stressed vowel, the first three formants at the halfway point of each sonorant, and of the first antiformant for the nasals will be presented. In addition, formant transitions were tracked going into and/or coming out of the sonorant consonant and will also be presented and discussed. [Research supported by UW-Madison Graduate School.]

4aSC22. The effect of talker image on phonetic convergence. Molly Babel (Dept. of Linguist., UC Berkeley, 1203 Dwinelle Hall, Berkeley, CA 94720-2650, mbabel@berkeley.edu)

This paper reports on an experiment that examines the socially motivated status of phonetic convergence. This is done by comparing social and asocial conditions in a lexical shadowing task. The social condition includes a photo of the talker while the asocial condition does not. The lexical shadowing task consists of the presentation of 50 low-frequency monosyllabic words with the vowels /i ae a o u/ six times each. Participants are also recorded reading the word list in pretask and post-task readings. Acoustic analyses are underway to identify differences in level of phonetic convergence in participants' productions in the two conditions ($n = 20$ in each condition) by comparing productions in the shadowing task to the pretask base line recordings. The results of this experiment contribute to the discussion regarding the status of phonetic convergence as a socially motivated process or a natural reflex that stems from the relationship between speech perception and speech production. This work has clear implications for theories of language change in addition to addressing issues regarding exemplar-based theories of speech production, the relationship between speech perception and production, and the perception and encoding of talker-specific characteristics.

4aSC23. Variation in stop consonant voicing in two regional varieties of American English. Ewa Jacewicz, Robert Allen Fox, and Samantha Lyle (Speech Percept. and Acoust. Labs, Ohio State Univ., 1070 Carmack Rd., Columbus, OH 43210, jacewicz.1@osu.edu)

This study is an acoustic investigation of the nature and extent of consonant voicing of the stop /b/ in two dialectal varieties of American English spoken in south-central Wisconsin and western North Carolina. The stop /b/ occurred at the juncture of two words such as *small bids*, in a position between two voiced sonorants, i.e., the liquid /l/ and a vowel. Twenty women participated, ten representing the Wisconsin and the North Carolina variety, respectively. Significant dialectal differences were found in the voicing patterns. The Wisconsin stop closures were usually not fully voiced and terminated in a complete silence followed by a noisy and voiceless closure release, whereas North Carolina speakers produced mostly fully voiced closures. Further dialectal differences included the proportion of closure voicing as a function of word emphasis. For Wisconsin speakers, the proportion of closure voicing was smallest when the word was emphasized and it was greatest in nonemphatic positions. For North Carolina speakers, the degree of word emphasis did not have an effect on the proportion of closure voicing. The results are discussed in terms of differences in the way voicing is maintained during the closure by the speakers of respective dialects. [Work supported by NIH..]

THURSDAY MORNING, 13 NOVEMBER 2008 LEGENDS 8, 7:45 A.M. TO 12:00 NOON

Session 4aUW

Underwater Acoustics and Acoustical Oceanography: Acoustics of Harbors, Ports, and Shallow Navigable Waterways

Kyle M. Becker, Chair
Pennsylvania State Univ., Applied Research Lab., P.O. Box 30, State College, PA 16804-0030

Chair's Introduction—7:45

Contributed Papers

7:50

4aUW1. Acoustic characterization of harbors and ports. Kyle M. Becker, David L. Bradley, D. Christopher Barber (Appl. Res. Lab., Penn State Univ., P.O. Box 30, State College, PA 16804-0030), Michael L Zucker (Penn State Univ., State College, PA 16804-0030), and Andrew T. Kankey (Penn State Univ., University Park, PA 16802)

The use of acoustics has become increasingly important in shallow waterways including ports and harbors. Applications span a range of military, commercial, and recreational interests including mine detection, port protection, and diver interaction. Harbor environments present challenges to acoustic propagation that are not encountered in the deep ocean or more open shelf environments. Characteristics that contribute to the unique acoustic propagation characteristics include typically very shallow depths, highly variable ambient noise levels, the presence of strong scatterers, and tidal effects. In a typical harbor, even a 1- or 2-m tidal variation can represent a change of 10% or more in the water depth. In this work, *in situ* measurements of low-frequency acoustic propagation are presented for a harbor near Newport, RI. The objective was to assess the propagation channel from a finger pier in a confined harbor out to the main shipping channel in Narragansett Bay and incorporate the findings into acoustic propagation models for this and similar environments. Of particular interest are the effects of tidal variations and changing background noise levels on the ability to detect different signals. [Work supported by ONR.]

8:05

4aUW2. Linear array beamforming in harbor environments. Christopher Barber, Kyle M. Becker, David L. Bradley (Penn. State Univ., Appl. Res. Lab., P.O. Box 30, State College, PA 16804-0030), Michael L. Zucker (Penn. State Univ., State College, PA 16804-0030), and Andrew T. Kankey (Penn. State Univ., University Park, PA 16802)

The use of linear arrays of sources to focus low-frequency sound on a target zone of limited spatial extent in a very shallow water environment is a topic of current interest for applications such as harbor defense. While linear array beamforming provides a starting point, the analytical expressions for beam response of a line array found in standard acoustics texts are developed for arrays of compact simple sources in a free-field environment. In contrast, the typical harbor environment is characterized by very shallow water depths, varying bottom conditions, irregular vertical boundaries, and the presence of multiple scattering bodies. In addition to environmental conditions, the size and cost of low- frequency sources limit the validity of the simple source assumption and impose practical limits on the number of

sources and maximum aperture length. Standard beamforming calculations are compared to measured data from a June 2008 harbor acoustic propagation experiment to quantify limitations of the linear array theory in estimating the beam response and three-dimensional sound field generated by an array of a small number of noncompact low-frequency sound sources in a real harbor environment. The relative impacts of environmental factors and source characteristics are also discussed.

8:20

4aUW3. Acoustic propagation in a shallow water duct with large obstructions. Michael Zucker, David Bradley, and Kyle Becker (ARL-Penn State Acoust., Appl. Sci. Bldg., North Atherton St., State College, PA 16802)

The characteristics of shallow water harbor or mooring environments present unique challenges to an acoustic propagation modeler. Established acoustic propagation codes were developed to address problems in deep water or more open shallow water environments where spherical or cylindrical geometries and one-way propagation approximations can easily be employed. In shallow harbors, large structures, including pier pilings and deep-draft vessels, that represent a significant blockage of the water-column propagation path may need to be accounted for. It is of interest to predict the received levels of the acoustic field transmitted past these obstructions. In order to more easily and accurately represent the complicated geometry of the boundary conditions encountered in this environment, a finite element model (COMSOL) is used. Using this model, predictions of the impact on low-frequency acoustic propagation by structures typically encountered in a harbor are made.

8:35

4aUW4. Focusing sound in coastal environments. Andrew T. Kankey, Gary H. Koopmann (Dept. of Mech. Eng., Penn State Univ., 157 Hammond Bldg., Univ. Park, PA 16802, atk127@psu.edu), Kyle M. Becker, and David L. Bradley (Penn State Univ., University Park, PA 16802)

An investigation of the ability to focus low-frequency acoustic energy in very shallow water was carried out in a semiprotected harbor in June 2008. From the end of a finger pier, a linear array of seven acoustic sources was suspended 2 m from the harbor bottom. The mean water depth in the harbor was 11 m with surficial sediments characterized by silts, sandy silts, and clay. The acoustic field was measured by an array of 11 hydrophones oriented in a cross pattern in the harbor. The phones ranged from 100 to 325 m from the center of the array. The objective of this work was to explore alternative methods to time-delay beamforming for focusing the sound field in the harbor. The approach is based on optimizing the phase of the individual sources to provide maximum sound pressure levels at a particular location in the harbor. The optimization scheme requires *a priori* interrogation of the harbor with a number of hydrophones in the area of interest. However, it is designed to be insensitive to vertical boundaries and other obstructions that can be found in typical working harbors. Results from recent field work are discussed.

8:50

4aUW5. Impulse response and acoustic fluctuation of high-frequency signals in a shallow water estuary. Sreeram Radhakrishnan and Alexander Sutin (Ctr. for Maritime Systems, Stevens Inst. of Technol., 711 Hudson St., Hoboken, NJ 07030)

Measurements of channel impulse response and its fluctuations in shallow water areas can be used for the prediction of sonar performance, the estimation of active and passive acoustic diver detections, and the prediction of channel characteristics relevant to underwater communication. A shallow water high-frequency propagation experiment was conducted in the Hudson River near Hoboken, NJ by the Maritime Security Laboratory at Stevens Institute of Technology. Acoustic propagation from an omnidirectional emitter to a receiver was investigated in the frequency band from 20 to 100 kHz for distances up to 100 m in a water depth of 8 m. Frequency sweep signal application was allowed for optimal analysis of the channel impulse response in a wide frequency band. Eigenrays corresponding to direct, surface-reflected, and bottom-reflected arrival paths were traced using the BELLHOP program. The fluctuation statistics of narrowband impulse responses for direct, surface-reflected, and bottom-reflected arrivals in different frequency bands was estimated. It was found that signals corresponding to the surface-reflected arrival show considerably higher temporal variation than direct and bottom-reflected arrivals. Comparison of impulse response for near-surface and near-bottom source depths indicates that the bottom-reflected arrival undergoes significantly high attenuation. [Work supported by ONR Project N00014-05-1-0632: Navy Force Protection Technology Assessment Project.]

Invited Papers

9:05

4aUW6. Acoustic research in the Hudson River Estuary at the Stevens Maritime Security Laboratory. Alexander Sutin and Barry Bunin (Stevens Inst. of Techn., Hoboken, NJ 07030, asutin@stevens.edu)

Stevens Institute of Technology has established a Maritime Security Laboratory (MSL) as a national laboratory resource for government, industry, and universities to advance technologies for the protection of USN maritime infrastructure. Experiment instrumentation includes research vessels, a multiplicity of hydrophones and emitters, stand alone acoustic buoys, diver acoustic simulators, unmanned underwater vehicles (UUVs), and precision instrumentation placement capabilities. The in-river experiments are controlled remotely from a Visualization Center on campus. Acoustic research is supported by sound speed profile measurements, integrated video and acoustic tracking of surface events, and global positionlng system tracking of live divers. Recent results include determination of parameters defining the detection distance of a threat: source level, transmission loss, and ambient noise. The combination of acoustic noise with video data for different kinds of ships in the Hudson River enables estimation of sound attenuation in a wide frequency band. The establishment of a library of various estuarine signatures, including divers, boats, ships, UUVs, construction equipment, and so forth, is underway. This knowledge can be used in a variety of intruder detection scenarios and for optimal methods of threat detection. [This work was supported by ONR Project N00014-05-1-0632: Navy Force Protection Technology Assessment Project.]

9:25

4aUW7. High-frequency one-way propagation experiments in Portsmouth Harbor, NH. Thomas C. Weber, Michelle Weirathmueller, and Larry Mayer (Cent. for Coastal and Ocean Mapping, Univ. of New Hampshire, Durham, NH 03824, weber@ccom.unh.edu)

Portsmouth Harbor is a shallow water estuary with 3-m tide heights and 2-m/s tidal currents, exhibiting strong mixing between ocean water and several fresh water inputs. In order to help characterize the limitations for underwater acoustic positioning systems in this environment, high-frequency (40 kHz) one-way acoustic propagation measurements were made at ranges up to 1 km in an area where the maximum depth reached 25 m. Synchronized acoustic transmissions were made from a bottom mounted projector as well as from a near-surface projector mounted on a moving research vessel. The signals were received at a pier-mounted hydrophone. Mea-

surements of signal levels and arrival times show strong signatures from a variety of phenomenon including changes in tide height, changes in sound speed gradients in response to the tidal forcing functions, and turbulent mixing in the water. Each of these will be discussed in relation to signal fluctuations and constraints on measuring pulse arrival times.

9:45

4aUW8. Impact of the harbor environment on the performance of a swimmer. Peter Stein (Sci. Solutions, Inc., 99 Perimeter Rd., Nashua, NH 03063, pstein@scisol.com)

Over the past several years, Scientific Solutions has been developing the Swimmer Detection Sonar Network (SDSN). It is a novel system that networks individual air-backed parabolic transducers which both transmit and receive in narrow beams. In this paper, system performance issues as related to operating in the port/harbor environment will be discussed. This includes effects due to clutter, noise, multipath propagation, refraction, and tides. Data collected from deployments in two different harbor environments will be used to explore the issues. Both harbors have similar water depths and bottom properties, but one is in a tropical climate, where the sound speed is essentially uniform year-round, and the other is a temperate (midlatitude) climate where the sound speed varies significantly depending on the time of year. The tests in the latter environment were conducted during the summer when the sound speed was strongly downward refracting. The methods by which the SDSN design overcomes the performance issues discussed will also be explored [Work supported by ONR.]

10:05—10:20 Break

10:20

4aUW9. Detection and localization performance using a forward scattering tripwire concept for harbor surveillance. Thomas Folegot (NATO Undersea Res. Ctr., Appl. Res., Viale San Bartolomeo 400, La Spezia, Italy)

An innovative technique has been developed to localize intruders crossing an acoustic underwater tripwire surveillance system in shallow water chokepoints. In the context of defence against terrorism, an sample application would be the permanent autonomous detection and localization of small underwater vehicles or divers surreptitiously entering a friendly harbor. The proposed method uses forward propagation and produces an acoustic image of the whole underwater entrance of a harbor, scanning and checking for intrusion in the area of interest. It is anticipated that the system could provide a high image rate and improved performance in noisy, reverberating, and changing environment. This paper discusses results obtained from a scaled tank experiment and shows preliminary results at sea.

10:40

4aUW10. Acoustical characteristics of muddy sediments. William M. Carey and Allan D. Pierce (Dept. of Mech. Eng., College of Engineeering, Boston Univ., 110 Cummington St., Boston, MA 02215)

Muddy sediments found in rivers, deltas, and harbors are classified as slow bottoms and pose a problem for the detection of buried ordnance. The questions for mud discussed here are as follows: First, can the frequency dependence dispersion characteristic be predicted and verified by measurements in areas where buried object detection is required? Second, what is the optimum yet simplest method of calculating sound scattering from buried compact but complex shaped objects? Wood and Weston [Acustica, V**14**, (1964)] indicated that muddy sediments have a compressional speed 3% less than that of water with a linear frequency dependent attenuation (less than that of sand) in the kilohertz range. This paper reviews experiments performed on muddy sediments at frequencies greater than a kilohertz and compares them to recent experimental measurements in pond sediments. The importance of gas content and bubbles is discussed. Gas content and bubbles are shown to be important factors in the reverberation from these slow bottoms. A theoretical treatment of "muddy sediments" is used to estimate the dispersion characteristic mud and to place limits on the use of sonar to find buried objects such as unexploded ordnance in the presence of reverberation due to gaseous inclusions. [Work sponsored by the Strategic Environmental Research and Development Program.]

Contributed Papers

11:00

4aUW11. Card-house theory of mud sediments containing kaolinite and its acoustical implications. Allan D. Pierce, William M. Carey, and Tyrone M. Porter (Dept. of Mech. Eng., Boston Univ., Boston, MA 02215, adp@bu.edu)

A major component of harbor mud is the clay mineral kaolinite, $Al_2Si_2O_5(OH)_4$. Isomorphous substitution, Al atoms occasionally replacing Si atoms, causes a net positive charge of roughly one electronic charge per 400 Si atoms. Kaolinite platelets have diameters and thicknesses of the order of 1 μm and 20 nm. The platelet's positive charge induces a thin negative charge layer of suspended negative ions on both sides, layer thickness dependent on temperature, creating a continuous sheet of transversely aligned longitudinal electrical quadrupoles. Platelets repel each other weakly when placed face to face. The natural configuration is where the only connection between platelets are with the edge of one touching the center of the face of another. The resulting configuration resembles a house of cards. Because the platelets are thin, the porosity is close to unity, and the sound speed is slightly less than the sound speed in water. This type of mud weakly resists shear because any shearing leads to an increase in electrostatic energy within the card house. Theories are presented to answer why bubbles in mud tend to have a flattened shape and to explain the small but nonzero attenuation of sound in mud. [Work sponsored by Strategic Environmental Research and Development Program.]

11:15

4aUW12. Automated passive acoustic intruder detection based on correlation approach. Alexander Sedunov, Laurent Fillinger, and Alexander Sutin (Davidson Lab., Stevens Inst. of Technol., 711 Hudson St., Hoboken, NJ 07030, asedunov@stevens.edu)

We consider the problem of passive acoustic detection of intruders in shallow waters using the signals acquired from multiple hydrophones. The suggested approach uses correlation of the acoustic signals recorded by different hydrophones as well as other features such as periodicity. Cross correlation of signals is conducted within a sliding window after passing through a multiband filter bank. This multiband filtering allows leveraging

the intrinsic spectral properties of emitted signals to discriminate intruder emission from acoustic noise sources such as ship traffic typically present in the river. Further heuristic processing exploits the periodic nature of signals such as human breathing, by detecting the beginnings and endings of the diver's inhalation signals. The detector assesses whether the recognized features are consistent with previously documented breathing rates in order to automatically and robustly detect the presence of a diver. The developed approach was applied in diver detection tests conducted in the Hudson River estuary where cross-correlation technique allowed finding the line of bearing to a diver. The challenges to implementation of such method in a standalone acoustic buoy under development at Stevens are also discussed. [This work was supported by ONR Project No. N00014-05-1-0632: Navy Force Protection Technology Assessment Project].

11:30

4aUW13. Finite difference time-domain simulation of Scholte wave generation and propagation along a shallow waterway bottom containing an anomaly. Thomas Muir (Natl. Ctr. for Physical Acoust., Univ. of Mississippi, One Coliseum Dr., University, MS 38677, tmuir@olemiss.edu) and Dwynn Lafleur (Univ. of Louisiana at Lafayette, Lafayette, LA 70504)

Results are presented on a two-dimensional simulation of the generation and propagation of a Scholte wave pulse along a water-sediment interface in a shallow water waveguide, consisting of 12.5 m of water, overlying a like depth of sand sediment. An underwater sound source, 2.5 m above the sediment, generates a low-frequency Ricker wavelet, which propagates as "modal tone bursts" in the waveguide and the sediment. Some of the energy is partitioned into a propagating Scholte wave mode at the sediment interface, a planar surface containing an "anomaly," i.e. a moundlike feature. Acoustic leakage into the elastic sediment is demonstrated, as is the propagation of the Scholte wave impulse moving along the interface and traveling over the anomaly, at a much slower velocity than its acoustic mode counterpart in the water column. The results are presented as a movie sequence, composed of snapshots of the spatial amplitude distribution of the Scholte wave as it propagates. Also presented are the modeled seismometer signals, yielding a two-dimensional particle velocity (hodographs) in the vertical plane at the anomaly, and somewhat beyond it. The significance of low-frequency Scholte waves in the acoustics of extremely shallow water is discussed.

11:45

4aUW14. A model of distant shipping noise. Cathy Ann Clark, Randall T. May, and Kristy A. Moore (NUWC-DIVNPT, 1176 Howell St., Newport, RI 02841)

Shipping noise from high-density areas is believed to migrate down the coastal shelf and propagate to long ranges via the deep sound channel, resulting in an increase in noise level at low angles for submerged receivers. A propagation calculation, which is applicable when a high degree of cycle mixing results in nearly random summation of path effects, is introduced and used to predict low-frequency (1–300 Hz), long range shipping noise. The vertical directionality of the noise is computed by fitting a source distribution within the deep sound channel by the method of least squares. Comparisons to a limited number of low-frequency measured data sets are presented.

THURSDAY AFTERNOON, 13 NOVEMBER 2008 LEGENDS 9, 1:30 TO 4:25 P.M.

Session 4pAA

Architectural Acoustics: Innovative Integration of Acoustic Treatment into Modern Architecture

Scott D. Pfeiffer, Cochair
Threshold Acoustics LLC, 53 W. Jackson Blvd., Ste. 1734, Chicago, IL 60604

Molly K. Norris, Cochair
Threshold Acoustics LLC, 53 W. Jackson Blvd., Ste. 1734, Chicago, IL 60604

Chair's Introduction—1:30

Invited Papers

1:35

4pAA1. Development of special acoustic materials for the Experimental Media and Performing Arts Center at Rensselaer Polytechnic Institute: Part 1. Carl Giegold (Threshold Acoust., 53 W. Jackson Blvd., Ste. 1734, Chicago, IL 60604, cgiegold@thresholdacoustics.com)

A series of project-specific interior acoustic elements were developed for the eMPAC project. Most prominent is the fabric ceiling in the concert hall, which was developed in tandem with the canopy of a similar material recently installed in London's Royal Festival Hall. Other concert hall finishes were also the subject of much mathematical and physical study during the design process. In the two studios, the finishes respond to the client's acoustic metaphor of a forest clearing, where the acoustic response is relatively alive but highly diffuse at mild and high frequencies. A system of GFRG panels, each of which has several different scales of shaping, was devised and empirically tested in several iterations to achieve the desired result.