Session 3aAA

Architectural Acoustics and Noise: Design and Performance of Office Workspaces in High Performance Buildings

Kenneth P. Roy, Chair
Armstrong World Industries, 2500 Columbia Ave., Lancaster, PA 17604

Chair's Introduction—8:20

Invited Papers

8:25

3aAA1. Architecture and acoustics … form and function—What comes 1st? Kenneth Roy (Armstrong World Industries, 2500 Columbia Ave., Lancaster, PA 17604, kproy@armstrong.com)

When I first studied architecture, it was expected that "form fits function" was pretty much a mantra to design. But is that the case today or has it ever been when acoustics are concerned? Numerous post occupancy studies of worker satisfaction with office IEQ indicate that things are not as they should be. And, as a matter of fact, high performance green buildings seem to fair much worse than normal office buildings when acoustic quality is considered. So what are we doing wrong—maybe the Gensler Workplace Study and other related studies could shed light on what is wrong, and how we might think differently about office design. From an acousticians viewpoint it's all about "acoustic comfort" meaning the right amount of intelligibility, privacy, and distraction for the specific work function. Times change and work functions change, so maybe we should be looking for a new mantra … like "function drives form." We may also want to consider that office space may need to include a "collaboration zone" where teaming takes place, a "focus zone" where concentrated thought can take place, and a "privacy zone" where confidential discussions can take place. Each of these requires different architecture and acoustic performance.

8:45

3aAA2. Acoustics in collaborative open office environments. John J. LoVerde, Samantha Rawlings, and David W. Dong (Veneklasen Assoc., 1711 16th St., Santa Monica, CA 90404, jloverde@veneklasen.com)

Historically, acoustical design for open office environments focuses on creating workspaces that maximize speech privacy and minimize aural distractions. Hallmark elements of the traditional open office environment include barriers, sound-absorptive surfaces, and consideration of workspace orientation, size, and background sound level. In recent years, development of "collaborative" office environments has been desired, which creates an open work setting, allowing immediate visual and aural communication between team members. This results in reducing the size of workstations, lowering barriers, and reducing distance between occupants. Additionally, group meeting areas have also become more open, with the popularization of "huddle zones" where small groups hold meetings in an open space adjacent to workstations rather than within enclosed conference rooms. Historically, this type of office environment would have poor acoustical function, with limited speech privacy between workstations and minimal attenuation of distracting noises, leading to occupant complaints. However, these collaborative open office environments function satisfactorily and seem to be preferred by occupants and employers alike. This paper investigates the physical acoustical parameters of collaborative open office spaces.

9:05

3aAA3. Lessons learned in reconciling high performance building design with acoustical comfort. Valerie Smith and Ethan Salter (Charles M. Salter Assoc., 130 Sutter St., Fl. 5, San Francisco, CA 94104, valerie.smith@cmsalter.com)

In today's diverse workplace, "the one size fits all" approach to office design is becoming less prevalent. The indoor environmental quality of the workplace is important to owners and occupants. Architects are developing innovative ways to encourage interaction and collaboration while also increasing productivity. Many of these ideas are at odds with the traditional acoustical approaches used for office buildings. Employees are asking for, and designers are incorporating, amenities such as kitchens, game rooms, and collaboration spaces into offices. Architects and end users are becoming increasingly aware of acoustics in their environment. The U.S. General Services Administration (GSA) research documents, as well as those from other sources, discusses the importance of acoustics in the workplace. Private companies are also creating acoustical standards documents for use in design of new facilities. As more buildings strive to achieve sustainable benchmarks (whether corporate, common green building rating systems such as LEED, or code-required) the understanding of the need for acoustical items (such as sound isolation, speech privacy, and background noise) also become critical. The challenge is how to reconcile sustainable goals with acoustical features. This presentation discusses several of the approaches that our firm has recently used in today's modern office environment.

Contributed Papers

9:25

3aAA4. I can see clearly now, but can I also hear clearly now too? Patricia Scanlon, Richard Ranft, and Stephen Lindsey (Longman Lindsey, 1410 Broadway, Ste. 508, New York, NY 10018, patricias@longmanlindsey.com)

The trend in corporate workplace has been away from closed plan gypsum board offices to open plan workstations and offices with glass fronts, sliding doors, and clearstories or glass fins in the wall between offices. These designs are often a kit of parts supplied by manufacturers, who offer minimal information on the sound transmission that will be achieved in practice. This results in end users who are often misled into believing they will enjoy a certain level of speech privacy in their offices. Our presentation will discuss the journey from benchmarking the NIC rating of an existing office construction, reviewing the STC ratings for various glass front options, evaluating details including door frame, door seals, intersection between office demising walls and front partition systems. We will then present how this information is transferred to the client, allowing them to make an informed decision on the construction requirements for their new space. We will highlight the difference in acoustical environment between what one might expect from reading manufacturer's literature, and what is typically achieved in practice.

9:40

3aAA5. Acoustics in an office building. Sergio Beristain (IMA, ESIME, IPN, P.O.Box 12-1022, Narvarte, Mexico City 03001, Mexico, sberista@hotmail.com)

New building techniques tend to make better use of materials, temperature, and energy, besides costs. A building company had to plan the adaptation of a very old building with the purpose to install private offices of different sizes in each floor, in order to take advantage of a large solid construction, reducing building time, total weight, etc., while at the same time fulfilling new requirements related with comfort, general quality, functionality, and economy. Among several other topics, sound and vibrations had to be considered during the process, including noise control and speech privacy, because a combination of private rooms and open plan offices were needed, as well as limiting environmental vibrations. Aspects such as the use of light weight materials and the installation of many climate conditioning systems were needed, which were dealt along the project in the search for a long lasting and low maintenance costs construction.

9:55–10:10 Break

Invited Papers

10:10

3aAA6. A case history in architectural acoustics: Security, acoustics, the protection of personally identifiable information (PII), and accessibility for the disabled. Donna A. Ellis (The Div. of Architecture and Eng., The Social Security Administration, 415 Riggs Ave., Severna Park, MD 21146, Donna.a.ellis@ssa.gov)

This paper discusses the re-design of a field office to enhance the protection of Personally Identifiable Information (PII), physical security, and accessibility for the disabled at the Social Security Administration (SSA) field office in Roxbury, MA. The study, and its results can be used at federal, civil, and private facilities where transaction window type public interviews occur. To protect the public and its staff, the SSA has mandated heightened security requirements in all field offices. The increased security measures include: Installation of barrier walls to provide separation between the public and private zones; maximized lines of sight, and increased speech privacy for the protection of PII. This paper discusses the use of the Speech Transmission Index (STI) measurement method used to determine the post construction intelligibility of speech through the transaction window, the acoustical design of the windows and their surrounding area, how appropriate acoustic design helps safeguard personal and sensitive information so that it may be securely communicated verbally, as well as improved access for the disabled community, especially the hearing impaired.

10:30

3aAA7. High performance medical clinics: Evaluation of speech privacy in open-plan offices and examination rooms. Steve Pettyjohn (The Acoust. & Vib. Group, Inc., 5765 9th Ave., Sacramento, CA CA, spettyjohn@acousticsandvibration.com)

Speech privacy evaluations of open plan doctors' offices and examination rooms were done at two clinics. One was in Las Vegas and the other in El Dorado Hills. The building were designed to put doctors closer to patients and for a cost savings. ASTM E1130, ASTM E336, and NRC guidelines were used to evaluate these spaces. For E1130, sound is produced at the source location with calibrated speakers, then measurements are made at receiver positions. The speaker faces the receiver. Only open plan furniture separated the source from the receiver. The examination rooms used partial height walls with a single layer of gypsum board on each face. Standard doors without seals were used. CAC 40 rated ceiling tile were installed. The cubicle furniture included sound absorption and was 42 to 60 in. tall. The Privacy Index was quite low, ranging from 30 to 66%. The NIC rating of the walls without doors ranged from 38 to 39, giving PI ratings of 83 to 84%. With a door, the NIC rating was 30 to 31 with PI ratings of 72. These results do not meet the requirements of the Facility Guideline Institute or ANSI 12 Working Group 44.

10:50

3aAA8. Exploring the impacts of consistency in sound masking. Niklas Moeller and Ric Doedens (K.R. Moeller Assoc. Ltd., 1050 Pachino Court, Burlington, ON L7L 6B9, Canada, rdoedens@logison.com)

Electronic sound masking systems control the noise side of the signal-to-noise ratio in interior environments. Their effectiveness relates directly to how consistently the specified masking curve is achieved. Current system specifications generally allow a relatively wide range in performance, in large part reflecting expectations set by legacy technologies. This session presents a case study of sound masking measurements and speech intelligibility calculations conducted in office spaces. These are used as a foundation to discuss the impacts of local inconsistencies in the masking sound and to begin a discussion of appropriate performance requirements for masking systems.

11:10

3aAA9. Evaluating the effect of prominent tones in noise on human task performance. Joonhee Lee and Lily M. Wang (Durham School of Architectural Eng. and Construction, Univ. of Nebraska - Lincoln, 1110 S. 67th St., Omaha, NE 68182-0816, joonhee.lee@huskers.unl.edu)

Current noise guidelines for the acoustic design of offices generally specify limits on loudness and sometimes spectral shape, but do not typically address the presence of tones in noise as may be generated by building services equipment. Numerous previous studies indicate that the presence of prominent tones is a significant source of deteriorating indoor environmental quality. Results on how prominent tones in background noise affect human task performance, though, are less conclusive. This paper presents results from recent studies at Nebraska on how tones in noise may influence task performance in a controlled office-like environment. Participants were asked to complete digit span tasks as a measure of working memory capacity, while exposed to assorted noise signals with tones at varying frequencies and tonality levels. Data on the percent correct and reaction time in which participants responded to the task are analyzed statistically. The results can provide guidance for setting limits on the tonality levels in offices and other spaces in which building users must be task-productive.

Contributed Paper

11:30

3aAA10. Optimal design of multi-layer microperforated sound absorbers. Nicholas Kim, Yutong Xue, and J. S. Bolton (Ray W. Herrick Labs., School of Mech. Eng., Purdue Univ., 177 S. Russell St., West Lafayette, IN, kim505@purdue.edu)

Microperforated polymer films can offer and effective solution when it is desired to design fiber-free sound absorption systems. The acoustic performance of the film is determined by hole size and shape, by the surface porosity, by the mass per unit area of the film, and by the depth of the backing air layer. Single sheets can provide good absorption over a one of two octave range, but if absorption over a broader range is desired, it is necessary to use multilayer treatments. Here the design of a multilayer sound absorption system is described, where the film is considered to have a finite mass per unit area and also to have conical perforations. It will be shown that it is possible to design compact absorbers that yield good performance over the whole speech interference range. In the course of the optimization it has been found that there is a tradeoff between cone angle and surface porosity. The design of lightweight, multilayer functional absorbers will also be described, and it will be shown, for example, that it is possible to design systems that simultaneously possess good sound absorption and barrier characteristics.

Session 3aAB

Animal Bioacoustics: Predator–Prey Relationships

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Chair's Introduction—8:25

Invited Papers

8:30

3aAB1. Breaking the acoustical code of ants: The social parasite's pathway. Francesca Barbero, Luca P. Casacci, Emilio Balletto, and Simona Bonelli (Life Sci. and Systems Biology, Univ. of Turin, Via Accademia Albertina 13, Turin 10123, Italy, francesca.barbero@unito.it)

Ant colonies represent a well-protected and stable environment (temperature, humidity) where essential resources are stored (e.g., the ants themselves, their brood, stored food). To maintain their social organization, ants use a variety of communication channels, such as the exchange of chemical and tactile signals, as well as caste specific stridulations (Casacci *et al.* 2013 Current Biology 23, 323–327). By intercepting and manipulating their host's communication code, about 10,000 arthropod species live as parasites and exploit ant nests. Here, we review results of our studies on *Maculinea* butterflies, a group of social parasites which mimic the stridulations produced by their host ants to promote (i) their retrieval into the colony (adoption: Sala *et al.* 2014, PLoS ONE 9(4), e94341), (ii) their survival inside the nest/brood chambers (integration: Barbero *et al.* 2009 J. Exp. Biol. 218, 4084–4090), or (iii) their achievement of the highest possible social status within the colony's hierarchy (full integration: Barbero *et al.* 2009, Science 323, 782–785). We strongly believe that the study of acoustic communication in ants will bring about significant advances in our understanding of the complex mechanisms underlying the origin, evolution, and stabilization of many host–parasite relationships.

8:50

3aAB2. How nestling birds acoustically monitor parents and predators. Andrew G. Horn and Martha L. Leonard (Biology, Dalhousie Univ., Life Sci. Ctr., 1355 Oxford St., PO Box 15000, Halifax, NS B3H 4R2, Canada, aghorn@dal.ca)

The likelihood that nestling songbirds survive until leaving the nest depends largely on how well they are fed by parents and how well they escape detection by predators. Both factors in turn are affected by the nestling's begging display, a combination of gaping, posturing, and calling that stimulates feedings from parents but can also attract nest predators. If nestlings are to be fed without being eaten themselves, they must beg readily to parents but avoid begging when predators are near the nest. Here we describe experiments to determine how nestling tree swallows, *Tachycineta bicolor*, use acoustic cues to detect the arrival of parents with food and to monitor the presence of predators, in order to beg optimally relative to their need for food. We also discuss how their assessments vary in relation to two constraints: their own poor perceptual abilities and ambient background noise. Together with similar work on other species, our research suggests that acoustically conveyed information on predation risk has been an important selective force on parent-offspring communication. More generally, how birds acoustically monitor their environment to avoid predation is an increasingly productive area of research.

9:10

3aAB3. Acoustic preferences of frog-biting midges in response to intra- and inter-specific signal variation. Ximena Bernal (Dept. of Biological Sci., Purdue Univ., 915 W. State St., West Lafayette, IN 47906, xbernal@purdue.edu)

Eavesdropping predators and parasites intercept mating signals emitted by their prey and host gaining information that increases the effectiveness of their attack. This kind of interspecific eavesdropping is widespread across taxonomic groups and sensory modalities. In this study, sound traps and a sound imaging device system were used to investigate the acoustic preferences of frog-biting midges, *Corethrella* spp. (Corethrellidae). In these midges, females use the advertisement call produced by male frogs to localize them and obtained a blood meal. As in mosquitoes (Culicidae), a closely related family, female midges require blood from their host for egg production. The acoustic preferences of the midges were examined in the wild in response to intra- and interspecific call variation. When responding to call variation in túngara frogs (*Engystomops pustulosus*), frogs producing vocalizations with higher call complexity and call rate were preferentially attacked by the midges. Túngara frog calls were also preferred by frog-biting midges over the calls produced by a sympatric frog of similar size, the hourglass frog (*Dendrosophus ebbracatus*). The role of call site selection in multi-species aggregations is explored in relation to the responses of frog-biting midges. In addition, the use of acoustic traps and sound imaging devices to investigate eavesdropper-victim interactions are discussed.

9:30

3aAB4. Foraging among acoustic clutter and competition: Vocal behavior of paired big brown bats. Michaela Warnecke (Psychol. and Brain Sci., The Johns Hopkins Univ., 3400 N Charles St., Baltimore, MD 21218, michaela.warnecke@jhu.edu), Chen Chiu, Wei Xian (Psychol. and Brain Sci., The Johns Hopkins Univ., Baltimore, MD), Clement Cechetto (AGROSUP, Inst. Nationale Superieur des Sci. Agronomique, Dijon, France), and Cynthia F. Moss (Psychol. and Brain Sci., The Johns Hopkins Univ., Baltimore, MD)

In their natural environment, big brown bats forage for small insects in open spaces, as well as in the presence of acoustic clutter. While searching and hunting for prey, these bats experience sonar interference not only from densely cluttered environments, but also through calls from other conspecifics foraging close-by. Previous work has shown that when two bats fly in a relatively open environment, one of them may go silent for extended periods of time (Chiu *et al.* 2008), which may serve to minimize such sonar interference between conspecifics. Additionally, big brown bats have been shown to adjust frequency characteristics of their vocalizations to avoid acoustic interference from conspecifics (Chiu *et al.*, 2009). It remains an open question, however, in what way environmental clutter and the presence of conspecifics influence the bat's call behavior. By recording multichannel audio and video data of bats engaged in insect capture in an open and a cluttered space, we quantified the bats' vocal behavior. Bats were flown individually and in pairs in an open and cluttered room, and the results of this study shed light on the strategies animals employ to negotiate a complex and dynamic environment.

9:45

3aAB5. Sensory escape from a predator–prey arms race: Low amplitude biosonar beats moth hearing. Holger R. Goerlitz (Acoust. and Functional Ecology, Max Planck Inst. for Ornithology, Eberhard-Gwinner-Str, Seewiesen 82319, Germany, hgoerlitz@orn.mpg.de), Hannah M. ter Hofstede (Biological Sci., Dartmouth College, Hanover, NH), Matt Zeale, Gareth Jones, and Marc W. Holderied (School of Biological Sci., Univ. of Bristol, Bristol, United Kingdom)

Ultrasound-sensitive ears evolved in many nocturnal insects, including some moths, to detect bat echolocation calls and evade capture. Although there is evidence that some bats emit echolocation calls that are inconspicuous to eared moths, it is difficult to determine whether this was an adaptation to moth hearing or originally evolved for a different purpose. Here we present the first example of an echolocation counterstrategy to overcome prey hearing at the cost of reduced detection distance, providing an example of a predator outcompeting its prey despite the life-dinner-principle. Aerial-hawking bats generally emit high-amplitude echolocation calls to maximize detection range. Using comparative acoustic flight-path tracking of free-flying bats, we show that the barbastelle, *Barbastella barbastellus*, emits calls that are 10 to 100 times lower in amplitude than those of other aerial hawking bats. Model calculations demonstrate that only bats emitting such low-amplitude calls hear moth echoes before their calls are conspicuous to moths. We confirm that the barbastelle remains undetected by moths until close and preys mainly on eared moths, using moth neurophysiology in the field and fecal DNA analysis. This adaptive stealth echolocation allows the barbastelle to access food resources that are difficult to catch for high-intensity bats.

10:00–10:20 Break

Invited Papers

10:20

3aAB6. Cues, creaks, and decoys: Using underwater acoustics to study sperm whale interactions with the Alaskan black cod longline fishery. Aaron Thode (SIO, UCSD, 9500 Gilman Dr, MC 0238, La Jolla, CA 92093-0238, athode@ucsd.edu), Janice Straley (Univ. of Alaska, Southeast, Sitka, AK), Lauren Wild (Sitka Sound Sci. Ctr., Sitka, AK), Jit Sarkar (SIO, UCSD, La Jolla, CA), Victoria O'Connell (Sitka Sound Sci. Ctr., Sitka, AK), and Dan Falvey (Alaska Longline Fisherman's Assoc., Sitka, AK)

For decades off SE Alaska, sperm whales have located longlining fishing vessels and removed, or "depredated," black cod from the hauls. In 2004, the Southeast Alaska Sperm Whale Avoidance Project (SEASWAP) began deploying passive acoustic recorders on longline fishing gear in order to identify acoustic cues that may alert whales to fishing activity. It was found that when hauling, longlining vessels generate distinctive cavitation sounds, which served to attract whales to the haul site. The combined use of underwater recorders and video cameras also confirmed that sperm whales generated "creak/buzz" sounds while depredating, even under good visual conditions. By deploying recorders with federal sablefish surveys over two years, a high correlation was found between sperm whale creak rate detections and visual evidence for depredation. Thus passive acoustics is now being used as a low-cost, remote sensing method to quantify depredation activity in the presence and absence of various deterrents. Two recent developments will be discussed in detail: the development and field testing of acoustic "decoys" as a potential means of attracting animals away from locations of actual fishing activity, and the use of "TadPro" cameras to provide combined visual and acoustic observations of longline deployments. [Work supported by NPRB, NOAA, and BBC.]

10:40

3aAB7. Follow the food: Effects of fish and zooplankton on the behavioral ecology of baleen whales. Joseph Warren (Stony Brook Univ., 239 Montauk Hwy, Southampton, NY 11968, joe.warren@stonybrook.edu), Susan E. Parks (Dept. of Biology, Syracuse Univ., Syracuse, NY), Heidi Pearson (Univ. of Alaska, Southeast, Juneau, AK), and Kylie Owen (Univ. of Queensland, Gatton, QLD, Australia)

Active acoustics were used to collect information on the type, distribution, and abundance of baleen whale prey species such as zooplankton and fish at fine spatial (sub-meter) and temporal (sub-minute) scales. Unlike other prey measurement methods, scientific echosounder surveys provide prey data at a resolution similar to what a predator would detect in order to efficiently forage. Data from

several studies around the world shows that differences in prey type or distribution result in distinctly different baleen whale foraging behaviors. Humpback whales in coastal waters of Australia altered their foraging pattern depending on the presence and abundance of baitfish or krill. In Southeast Alaska, humpback whales foraged cooperatively or independently depending on prey type and abundance. Humpback whales in the Northwest Atlantic with multiple prey species available foraged on an energetically costly (and presumably rewarding) species. The vertical and horizontal movements of North Atlantic right whales in Cape Cod Bay were strongly correlated with very dense aggregations of copepods. In all of these cases, active acoustics were used to estimate numerical densities of the prey, which provides quantitative information about the energy resource available to foraging animals.

Contributed Papers

11:00

3aAB8. Association of low oxygen waters with the depths of acoustic scattering layers in the Gulf of California and implications for the success of Humboldt squid (*Dosidicus gigas*). David Cade (BioSci., Stanford Univ., 120 Oceanview Boulevard, Pacific Grove, CA 93950, davecade@stanford.edu) and Kelly J. Benoit-Bird (CEOAS, Oregon State Univ., Corvallis, OR)

The ecology in the Gulf of California has undergone dramatic changes over the past century as Humboldt squid (*Dosidicus gigas*) have become a dominant predator in the region. The vertical overlap between acoustic scattering layers, which consist of small pelagic organisms that make up the bulk of *D. gigas* prey, and regions of severe hypoxia have led to a hypothesis linking the shoaling of oxygen minimum zones over the past few decades to compression of acoustic scattering layers, which in turn would promote the success of *D. gigas*. We tested this hypothesis by looking for links between specific oxygen values and acoustic scattering layer boundaries. We applied an automatic layer detection algorithm to shipboard echosounder data from four cruises in the Gulf of California. We then used CTD data and a combination of logistic modeling, contingency tables, and linear correlations with parameter isolines to determine which parameters had the largest effects on scattering layer boundaries. Although results were inconsistent, we found scattering layer depths to be largely independent of the oxygen content in the water column, and the recent success of *D. gigas* in the Gulf of California is therefore not likely to be attributable to the effects of shoaling oxygen minimum zones on acoustic scattering layers.

11:15

3aAB9. Understanding the relationship between ice, primary producers, and consumers in the Bering Sea. Jennifer L. Miksis-Olds (Appl. Res. Lab, Penn State, PO Box 30, Mailstop 3510D, State College, PA 16804, jlm91@psu.edu) and Stauffer A. Stauffer (Office of Res. and Development, US Environ. Protection Agency, Washington, DC)

Technology has progressed to the level of allowing for investigations of trophic level interactions over time scales of months to years which were previously intractable. A combination of active and passive acoustic technology has been integrated into sub-surface moorings on the Eastern Bering Sea shelf, and seasonal transition measurements were examined to better understand how interannual variability of hydrographic conditions, phytoplankton biomass, and acoustically derived consumer abundance and community structure are related. Ocean conditions were significantly different in 2012 compared to relatively similar conditions in 2009, 2010, and 2011. Differences were largely associated with variations in sea ice extent, thickness, retreat timing, and water column stratification. There was a high degree of variability in the relationships between different classes of consumers and hydrographic condition, and evidence for intra-consumer interactions and trade-offs between different size classes was apparent. Phytoplankton blooms in each year stimulated different components of the consumer population. Acoustic technology now provides the opportunity to explore the ecosystem dynamics in a remote, ice-covered region that was previously limited to ship-board measurements during ice-free periods. The new knowledge we are gaining from remote, long-term observations is resulting in a re-examination of previously proposed ecosystem theories related to the Bering Sea.

11:30

3aAB10. Temporal and spatial patterns of marine soundscape in a coastal shallow water environment. Shane Guan (Office of Protected Resources, National Marine Fisheries Service, 1315 East-West Hwy., SSMC-3, Ste. 13728, Silver Spring, MD 20910, shane.guan@noaa.gov), Tzu-Hao Lin (Inst. of Ecology & Evolutionary Biology, National Taiwan Univ., Taipei, Taiwan), Joseph F. Vignola (Dept. of Mech. Eng., The Catholic Univ. of America, Washington, MD), LIen-Siang Chou (Inst. of Ecology & Evolutionary Biology, National Taiwan Univ., Taipei, Taiwan), and John A. Judge (Dept. of Mech. Eng., The Catholic Univ. of America, Washington, DC)

Underwater acoustic recordings were made at two coastal shallow water locations, Yunlin (YL) and Waishanding (WS), off Taiwan between June and December 2012. The purpose of the study was to establish soundscape baselines and characterize the acoustic habitat of the critically endangered Eastern Taiwan Strait Chinese white dolphin by investigating: (1) major contributing sources that dominant the soundscape, (2) temporal, spatial, and spectral patterns of the soundscape, and (3) correlations of known sources and their potential effects on dolphins. Results show that choruses from croaker fish (family Sciaenidae) were dominant sound sources in the 1.2–2.4 kHz frequency band for both locations at night, and noises from container ships in the 150–300 Hz frequency band define the relative higher broadband sound levels at YL. In addition, extreme temporal variation in the 150–300 Hz frequency band were observed at WS, which was shows to be linked to the tidal cycle and current velocity. Furthermore, croaker choruses are found to be most intense around the time of high tide at night, but not so around the time of low tide. These results illustrate interrelationships among different biotic, abiotic, and anthropogenic environmental elements that shape the unique fine-scale soundscape in a coastal environment.

Session 3aAO

Acoustical Oceanography, Underwater Acoustics, and Education in Acoustics: Education in Acoustical Oceanography and Underwater Acoustics

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Chair's Introduction—8:00

Invited Papers

8:05

3aAO1. Ocean acoustics education—A perspective from 1970 to the present. Arthur B. Baggeroer (Mech. and Elec. Eng., Massachusetts Inst. of Technol., Rm. 5-206, MIT, Cambridge, MA 02139, abb@boreas.mit.edu)

A very senior ocean acoustician is attributed with the quote to the effect "one does not start in ocean acoustics, but rather ends up in it." This may well summarize the issues confronting education in ocean acoustics. Acoustics were part of the curriculum in physics departments, whereas now it is spread across many departments. Acoustics and perhaps ocean acoustics are most often found in mechanical or ocean engineering departments, but seldom in physics. Almost all our pioneers from the WWII era were educated in physics and some more recently in engineering departments. Yet, only a few places maintained in depth curricula in ocean acoustics. Most education was done by one on one mentoring. Now the number of students is diminishing, whether because of perception of employment opportunities or the number of available assistantships is uncertain. ONR is the major driver in ocean acoustics for supporting graduate students. The concern about this is hardly new. Twenty plus years ago this was codified as part of the so called "Lackie Report" establishing ocean acoustics as "Navy unique" giving it a priority as a "Navy National Need" (NNR). With fewer students enrolled in ocean acoustics administrators at universities are really balking at sponsoring faculty slots, so there are very significant issues arising for an education in ocean acoustics. Perhaps, reverting to the original model of fundamental training in a related discipline followed by on the job training may be the only option for the future.

8:25

3aAO2. Joint graduate education program: Massachusetts Institute of Technology and Woods Hole Oceanographic Institution. Timothy K. Stanton (Dept. Appl. Ocean. Phys. & Eng., Woods Hole Oceanographic Inst., Woods Hole, MA 02543, tstanton@whoi.edu)

The 40 + year history of this program will be presented, with a focus on the underwater acoustics and signal processing component. Trends in enrollment will be summarized.

8:35

3aAO3. Graduate studies in underwater acoustics at the University of Washington. Peter H. Dahl, Robert I. Odom, and Jeffrey A. Simmen (Appl. Phys. Lab. and Mech. Eng. Dept., Univ. of Washington, Mech. Eng., 1013 NE 40th St., Seattle, WA 98105, dahl@apl.washington.edu)

The University of Washington through its Departments of Mechanical and Electrical Engineering (College of Engineering), Department of Earth and Space Sciences, and School of Oceanography (College of the Environment), and by way of its Applied Physics Laboratory, which links all four of these academic units, offers a diverse graduate education experience in underwater acoustics. A summary is provided of the research infrastructure, primarily made available through Applied Physics Laboratory, which allows for ocean going and arctic field opportunities, and course options offered through the four units that provide the multi-disciplinary background essential for graduate training in the field of underwater acoustics. Students in underwater acoustics can also mingle in or extend their interests into medical acoustics research. Degrees granted include both the M.S and Ph.D.

8:45

3aAO4. Acoustical Oceanography and Underwater Acoustics; their role in the Pennsylvania State University Graduate Program in Acoustics. David Bradley (Penn State Univ., PO Box 30, State College, PA 16870, dlb25@psu.edu) and Victor Sparrow (Penn State Univ., University Park, PA)

The Pennsylvania State University Graduate Program in Acoustics has a long and successful history in Acoustics Education. A brief history together with the current status of the program will be discussed. An important aspect of the program has been the strong role of the Applied Research Laboratory, both in support of the program as well as for the graduate students enrolled. Presentation includes details of course content, variability to fit student career goals and program structure, including resident and distance education opportunities. The future of the program at Penn State will also be addressed.

8:55

3aAO5. Ocean acoustics at the University of Victoria. Ross Chapman (School of Earth and Ocean Sci., Univ. of Victoria, 3800 Finnerty Rd., Victoria, BC V8P5C2, Canada, chapman@uvic.ca)

This paper describes the academic program in Ocean Acoustics and Acoustical Oceanography at the University of Victoria in Canada. The program was established when a Research Chair in Ocean Acoustics consisting of two faculty members was funded in 1995 by the Canadian Natural Sciences and Engineering Research Council (NSERC). The Research Chair graduate program offered two courses in Ocean Acoustics, and courses in Time Series Analysis and Inverse Methods. Funding for students was obtained entirely through partnership research programs with Canadian marine industry, the Department of National Defence in Canada and the Office of Naval Research. The program was successful in graduating around 30 M.Sc. and Ph.D. students to date, about half of whom were Canadians. Notably, all the students obtained positions in marine industry, government, or academia after their degrees. The undergraduate program consisted of one course in Acoustical Oceanography at the senior level (3rd year) that was designed to appeal to students in physics, biology, and geology. The course attracted about 30 students each time, primarily from biology. The paper concludes with perspectives on difficulties in operating an academic program with a low critical mass of faculty and in isolation from colleagues in the research field.

9:05

3aAO6. Ocean acoustics away from the ocean. David R. Dowling (Mech. Eng., Univ. of Michigan, 1231 Beal Ave., Ann Arbor, MI 48109-2133, drd@umich.edu)

Acoustics represents a small portion of the overall educational effort in engineering and science, and ocean acoustics is one of many topic areas in the overall realm of acoustics. Thus, maintaining teaching and research efforts involving ocean acoustics is challenging but not impossible, even at a university that is more than 500 miles from the ocean. This presentation describes the author's two decades of experience in ocean acoustics education and research. Success is possible by first attracting students to acoustics, and then helping them wade into a research topic in ocean acoustics that overlaps with their curiosity, ambition, or both. The first step occurs almost naturally since college students' experience with their ears and voice provides intuition and motivation that allows them to readily grasp acoustic concepts and to persevere through mathematical courses. The second step is typically no more challenging since ocean acoustics is a leading and fascinating research area that provides stable careers. Plus, there are even some advantages to studying ocean acoustics away from the ocean. For example, matched-field processing, a common ocean acoustic remote sensing technique, appears almost magical to manufacturing or automotive engineers when applied to assembly line and safety problems involving airborne sound.

9:15

3aAO7. Office of Naval Research special research awards in ocean acoustics. Robert H. Headrick (Code 32, Office of Naval Res., 875 North Randolph St., Arlington, VA 22203, bob.headrick@navy.mil)

The Ocean Acoustics Team of the Office of Naval Research manages the Special Research Awards that support graduate traineeship, postdoctoral fellowship, and entry-level faculty awards in ocean acoustics. The graduate traineeship awards provide for study and research leading to a doctoral degree and are given to individuals who have demonstrated a special aptitude and desire for advanced training in ocean acoustics or the related disciplines of undersea signal processing, marine structural acoustics and transducer materials science. The postdoctoral fellowship and entry-level faculty awards are similarly targeted. These programs were started as a component of the National Naval Responsibility in Ocean Acoustics to help ensure a stable pipeline of talented individuals would be available to support the needs of the Navy in the future. They represent only a fraction of the students, postdocs, and early faculty researchers that are actively involved the basic research supported by the Ocean Acoustics Program. A better understanding of the true size of the pipeline and the capacity of the broader acoustics related Research and Development community to absorb the output is needed to maintain a balance in priorities for the overall Ocean Acoustics Program.

9:25

3aAO8. Underwater acoustics education at the University of Texas at Austin. Marcia J. Isakson (Appl. Res. Labs., The Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78713, misakson@arlut.utexas.edu), Mark F. Hamilton (Mech. Eng. Dept. and Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX), Clark S. Penrod, Frederick M. Pestorius (Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX), and Preston S. Wilson (Mech. Eng. Dept. and Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX)

The University of Texas at Austin has supported education and research in acoustics since the 1930s. The Cockrell School of Engineering currently offers a wide range of graduate courses and two undergraduate courses in acoustics, not counting the many courses in hearing, speech, seismology, and other areas of acoustics at the university. An important adjunct to the academic program in acoustics has been the Applied Research Laboratories (ARL). Spun off in 1945 from the WW II Harvard Underwater Sound Laboratory (1941–1949) and founded as the Defense Research Laboratory, ARL is one of five University Affiliated Research Centers formally recognized by the US Navy for their prominence in underwater acoustics research and development. ARL is an integral part of UT Austin, and this

symbiotic combination of graduate and undergraduate courses, and laboratory and field work, provides one of the leading underwater acoustics education programs in the nation. In this talk, the underwater acoustics education program will be described with special emphasis on the underwater acoustics course and its place in the larger acoustics program. Statistics on education, funding, and placement of graduate students in the program will also be presented.

9:35

3aAO9. Acoustical Oceanography and Underwater Acoustics Graduate Programs at the Scripps Institution of Oceanography of the University of California, San Diego. William A. Kuperman (Scripps Inst. of Oceanogr., Univ. of California, San Diego, Marine Physical Lab., La Jolla, CA 92093-0238, wkuperman@ucsd.edu)

The Scripps Institution of Oceanography (SIO) of the University of California, San Diego (UCSD), has graduate programs in all areas of acoustics that intersect oceanography. These programs are associated mostly with internal SIO divisions that include the Marine Physical Laboratory, Physical Oceanography, Geophysics, and Biological Oceanography as well as SIO opportunities for other UCSD graduate students in the science and engineering departments. Course work includes basic wave physics, graduate mathematics, acoustics and signal processing, oceanography and biology, digital signal processing, and geophysics/seismology. Much of the emphasis at SIO includes at-sea experience. Recent examples of thesis research has been in marine mammal acoustics, ocean tomography and seismic/acoustic inversion methodology, acoustical signal processing, ocean ambient noise inversion, ocean/acoustic exploration, and acoustic sensing of the air-sea interaction. An overview of the SIO/UCSD graduate program is presented.

9:45

3aAO10. Underwater acoustics education at Portland State University. Martin Siderius and Lisa M. Zurk (Elec. and Comput. Eng., Portland State Univ., 1900 SW 4th Ave., Portland, OR 97201, siderius@pdx.edu)

The Northwest Electromagnetics and Acoustics Research Laboratory (NEAR-Lab) is in the Electrical and Computer Engineering Department at Portland State University (PSU) in Portland, Oregon. The NEAR-Lab was founded in 2005 and is co-directed by Lisa M. Zurk and Martin Siderius. A primary interest is underwater acoustics, and students at undergraduate and graduate levels (occasionally also high school students) regularly participate in research. This is synergistic with underwater acoustics education at PSU, which includes a course curriculum that provides opportunities for theoretical and experimental research and multiple course offerings at both the undergraduate and graduate level. The research generally involves modeling and analysis of acoustic propagation and scattering, acoustic signal processing, algorithm development, environmental acoustics, and bioacoustics. The lab maintains a suite of equipment for experimentation including hydrophone arrays, sound projectors, a Webb Slocum glider, an electronics lab, and an acoustic tank. Large-scale experiments that include student participation have been routinely conducted by successful collaborations such as with the APL-University of Washington, NATO Centre for Maritime Research and Experimentation, and the University of Hawaii. In this talk, the state of the PSU underwater acoustics program will be described along with the courses offered, research activities, experimental program, collaborations, and student success.

9:55

3aAO11. Underwater acoustics education in Harbin Engineering University. Desen Yang, Xiukun Li, and Yang Li (Acoust. Sci. and Technol. Lab., Harbin Eng. Univ., Harbin, Heilongjiang Province, China, dsyang@hrbeu.edu.cn)

College of Underwater Acoustic Engineering in Harbin Engineering University is the earliest institution engaging in underwater acoustics education in Chinese universities, which has complete types of high education training levels and subject directions. There are 124 teachers in the college engaging in underwater acoustics research, of which there are 30 professors and 36 associate professors. The developments of underwater acoustic transducer technology, underwater positioning and navigation technology, underwater target detecting technology, underwater acoustic communication technique, multi-beam echo sounding technique, and high resolution image sonar technique new theory and technology of underwater acoustic reach the leading level in China. Every year, the college attracts more than 200 excellent students whose entrance examination marks is 80 points higher than the key fraction stroke. There are three education program levels in this specialty (undergraduate-level, graduate-level, and Ph.D.-level), and students may study underwater acoustics within any of our three programs, besides which, the college has special education programs for foreign students. Graduate employments are underwater acoustic institution, electronic institution, communication company, and IT enterprise. In this paper, descriptions of underwater acoustics education programs, curriculum systems, and teaching contents of acoustics courses will be introduced.

10:05–10:20 Break

Contributed Papers

10:20

3aAO12. Graduate education in underwater acoustics, transduction, and signal processing at UMass Dartmouth. David A. Brown (Elec. and Comput. Eng., Univ. of Massachusetts Dartmouth, 151 Martine St., Fall River, MA 02723, dbAcoustics@cox.net), John Buck, Karen Payton, and Paul Gendron (Elec. and Comput. Eng., Univ. of Massachusetts Dartmouth, Dartmouth, MA)

The University of Massachusetts Dartmouth established a Ph.D. degree in Electrical Engineering with a specialization in Marine Acoustics in 1996, building on the strength of the existing M.S. program. Current enrollment in these programs include 26 M.S. students and 16 Ph.D. students. The program offers courses and research opportunities in the area of underwater acoustics, transduction, and signal processing. Courses include the Fundamentals of Acoustics, Random Signals, Underwater Acoustics, Introduction to Transducers, Electroacoustic Transduction, Digital Signal Processing, Detection Theory, and Estimation Theory. The university's indoor underwater acoustic test and calibration facility is one of the largest in academia and supports undergraduate and graduate thesis and sponsored research. The university also owns three Iver-2 fully autonomous underwater vehicles. The graduate program capitalizes on collaborations with many marine technology companies resident at the university's Advanced Technology and

Manufacturing Center (ATMC) and the nearby Naval Undersea Warfare Center in Newport, RI. The presentation will highlight recent theses and dissertations, course offerings, and industry and government collaborations that support underwater acoustics research.

10:30

3aAO13. Ocean acoustics at the University of Rhode Island. Gopu R. Potty and James H. Miller (Dept. of Ocean Eng., Univ. of Rhode Island, 115 Middleton Bldg., Narragansett, RI 02882, potty@egr.uri.edu)

The undergraduate and graduate program in Ocean Engineering at the University of Rhode Island is one of the oldest such programs in the United States. This program offers Bachelors, Masters (thesis and non-thesis options), and Ph.D. degrees. At the undergraduate level, students are exposed to ocean acoustics through a number of required and elective courses, laboratory and field work, and capstone projects. Examples of student projects will be presented. At the graduate level, students can specialize in several areas including geoacoustic inversion, propagation modeling, marine mammal acoustics, ocean acoustic instrumentation, transducers, etc. A historical review of the evolution of ocean acoustics education in the department will be presented. This will include examples of some of the research carried out by different faculty and students over the years, enrollment trends, collaborations, external funding, etc. Many graduates from the program hold faculty positions at a number of universities in the US and abroad. In addition, graduates from the ocean acoustics program at URI are key staff at many companies and organizations. A number of companies have spun off the program in the areas of forward-looking sonar, sub-bottom profiling, and other applications. The opportunities and challenges facing the program will be summarized.

10:40

3aAO14. An underwater acoustics program far from the ocean: The Georgia Tech case. Karim G. Sabra (Mech. Eng., Georgia Inst. of Technol., 771 Ferst Dr., NW, Atlanta, GA 30332-0405, karim.sabra@me.gatech.edu)

The underwater acoustics education program at the Georgia Institute of Technology (Georgia Tech) is run by members of the Acoustics and Dynamics research area group from the School of Mechanical Engineering. We will briefly review the scope of this program in terms of education and research activities as well as discuss current challenges related to the future of underwater acoustics education.

10:50

3aAO15. Graduate education in ocean acoustics at Rensselaer Polytechnic Institute. William L. Siegmann (Dept. of Mathematical Sci., Rensselaer Polytechnic Inst., 110 Eighth St., Troy, NY 12180-3590, siegmw@rpi.edu)

Doctoral and master's students in Rensselaer's Department of Mathematical Sciences have had opportunities for research in Ocean Acoustics since 1957. Since then only one or two faculty members at any time were directly involved with OA education. Consequently, collaboration with colleagues at other centers of OA research has been essential. The history will be briefly reviewed, focusing on the education of a small group of OA doctoral students in an environment with relatively limited institutional resources. Graduate education in OA at RPI has persisted because of sustained support by the Office of Naval Research.

11:00–11:45 Panel Discussion

11:45

3aAO16. Summary of panel discussion on education in Acoustical Oceanography and Underwater Acoustics. Andone C. Lavery (Appl. Ocean Phys. and Eng., Woods Hole Oceanographic Inst., 98 Water St., MS 11, Bigelow 211, Woods Hole, MA 02536, alavery@whoi.edu)

Following the presentations by the speakers in session, a panel discussion will offer the platform for those in the audience, particularly those from Institutions and Universities that did not formally participate in the session but have active education programs in Acoustical Oceanography and/or Underwater Acoustics, to ask relevant questions and contribute to the assessment of the national health of education in the fields of Acoustical Oceanography and Underwater Acoustics. A summary of the key points presented in the special sessions and panel discussion is provided.

Session 3aBA

Biomedical Acoustics: Kidney Stone Lithotripsy

Tim Colonius, Cochair
Mechanical Engineering, Caltech, 1200 E. California Blvd., Pasadena, CA 91125

Wayne Kreider, Cochair
CIMU, Applied Physics Laboratory, University of Washington, 1013 NE 40th Street, Seattle, WA 98105

Contributed Papers

8:00

3aBA1. Comparable clinical outcomes with two lithotripters having substantially different acoustic characteristics. James E. Lingeman, Naeem Bhojani (Urology, Indiana Univ. School of Medicine, 1801 N. Senate Blvd., Indianapolis, IN 46202, jlingeman@iuhealth.org), James C. Williams, Andrew P. Evan, and James A. McAteer (Anatomy and Cell Biology, Indiana Univ. School of Medicine, Indianapolis, IN)

A consecutive case study was conducted to assess the clinical performance of the Lithogold, an electrohydraulic lithotripter having a relatively low P+ and broad focal width (FW) (~20 MPa, ~20 mm), and the electromagnetic Storz-SLX having higher P+ and narrower FW (~50 MPa, 3–4 mm). Treatment was at 60 SW/min with follow-up at ~2 weeks. Stone free rate (SFR) was defined as no residual fragments remaining after single session SWL. SFR was similar for the two lithotripters (Lithogold 29/76 = 38.2%; SLX 69/142 = 48.6% p = 0.15), with no difference in outcome for renal stones (Lithogold 20/45 = 44.4%; SLX 33/66 = 50%, p = 0.70) or stones in the ureter (Lithogold 9/31 = 29%; SLX 36/76 = 47.4%, p = 0.08). Stone size did not differ between the two lithotripters for patients who were not stone free (9.1±3.7 mm for Lithogold vs. 8.5±3.5 mm for SLX, P = 0.42), but the stone-free patients in the Lithogold group had larger stones on average than the stone-free patients treated with the SLX (7.6±2.5 mm vs. 6.2±3.2 mm, P = 0.005). The percentage of stones that did not break was similar (Lithogold 10/76 = 13.2%; SLX 23/142 = 16.2%). These data present a realistic picture of clinical outcomes using modern lithotripters, and although the acoustic characteristics of the Lithogold and SLX differ considerably, outcomes were similar. [NIH-DK43881.]

8:15

3aBA2. Characterization of an electromagnetic lithotripter using transient acoustic holography. Oleg A. Sapozhnikov, Sergey A. Tsysar (Phys. Faculty, Moscow State Univ., Leninskie Gory, Moscow 119991, Russian Federation, oa.sapozhnikov@gmail.com), Wayne Kreider (Ctr. for Industrial and Medical Ultrasound, Appl. Phys. Lab., Univ. of Washington, Seattle, WA), Guangyan Li (Dept. of Anatomy and Cell Biology, Indiana Univ. School of Medicine, Indianapolis, IN), Vera A. Khokhlova (Ctr. for Industrial and Medical Ultrasound, Appl. Phys. Lab., Univ. of Washington, Seattle, WA), and Michael R. Bailey (Dept. of Urology, Univ. of Washington Medical Ctr., Seattle, WA)

Shock wave lithotripters radiate high intensity pulses that are focused on a kidney stone. High pressure, short rise time, and path-dependent nonlinearity make characterization in water and extrapolation to tissue difficult. Here acoustic holography is applied for the first time to characterize a lithotripter. Acoustic holography is a method to determine the distribution of acoustic pressure on the surface of the source (source hologram). The electromagnetic lithotripter characterized in this effort is a commercial model (Dornier Compact S, Dornier MedTech GmbH, Wessling, Germany) with 6.5 mm focal width. A broadband hydrophone (HGL-0200, sensitive diameter 200 μm, Onda Corp., Sunnyvale, CA) was used to sequentially measure the field over a set of points in a plane in front of the source. Following the previously developed transient holography approach, the recorded pressure field was numerically back-propagated to the source surface and then used for nonlinear forward propagation to predict waveforms in different points in the focal region. Pressure signals predicted from the source hologram coincide well with the waveforms measured by a fiber optic hydrophone. Moreover, the method provides an accurate boundary condition from which the field in tissue can be simulated. [Work supported by RSF 14-15-00665 and NIH R21EB016118, R01EB007643, and DK043881.]

8:30

3aBA3. Multiscale model of comminution in shock wave lithotripsy. Sorin M. Mitran (Mathematics, Univ. of North Carolina, CB 3250, Chapel Hill, NC 27599-3250, mitran@amath.unc.edu), Georgy Sankin, Ying Zhang, and Pei Zhong (Mech. Eng. and Mater. Sci., Duke Univ., Durham, NC)

A previously introduced model for stone comminution in shock wave lithotripsy is extended to include damage produced by cavitation. At the macroscopic, continuum level a 3D elasticity model with time-varying material constants capturing localized damage provides the overall stress field within kidney stone simulants. Regions of high stress are identified and a mesoscopic crack propagation is used to dynamically update localized damage. The crack propagation model in turn is linked with a microscopic grain dynamics model. Continuum stresses and surface pitting is provided by a multiscale cavitation model (see related talk). The overall procedure is capable of tracking stone fragments and surface cavitation of the fragments through several levels of breakdown. Computed stone fragment distributions are compared to experimental results. [Work supported by NIH through 5R37DK052985-18.]

8:45

3aBA4. Exploring the limits of treatment used to invoke protection from extracorporeal shock wave lithotripsy induced injury. Bret A. Connors, Andrew P. Evan, Rajash K. Handa, Philip M. Blomgren, Cynthia D. Johnson, James A. McAteer (Anatomy and Cell Biology, IU School of Medicine, Medical Sci. Bldg., Rm. 5055, 635 Barnhill Dr., Indianapolis, IN 46202, bconnors@iupui.edu), and James E. Lingeman (Urology, IU School of Medicine, Indianapolis, IN)

Previous studies with our juvenile pig model have shown that a clinical dose of 2000 shock waves (SWs) (Dornier HM-3, 24 kV, 120 SWs/min) produces a lesion ~3–5% of the functional renal volume (FRV) of the SW-treated kidney. This injury was significantly reduced (to ~0.4% FRV) when a priming dose of 500 low-energy SWs immediately preceded this clinical dose, but not when using a priming dose of 100 SWs [BJU Int. 110, E1041 (2012)]. The present study examined whether using only 300 priming dose SWs would initiate protection against injury. METHODS: Juvenile pigs were treated with 300 SW's (12 kV) delivered to a lower pole calyx using a HM-3 lithotripter. After a pause of 10 s, 2000 SWs (24 kV) were delivered

3a WED. AM

to that same kidney. The kidneys were then perfusion-fixed and processed to quantitate the size of the parenchymal lesion. RESULTS: Pigs (n = 9) treated using a protocol with 300 low-energy priming dose SWs had a lesion measuring 0.84±0.43% FRV (mean ± SE). This lesion was smaller than that seen with a clinical dose of 2000 SWs at 24 kV. CONCLUSIONS: A treatment protocol including 300 low-energy priming dose SWs can provide protection from injury during shock wave lithotripsy. [Research supported by NIH grant P01 DK43881.]

9:00

3aBA5. Shockwave lithotripsy with renoprotective pause is associated with vasoconstriction in humans. Franklin Lee, Ryan Hsi, Jonathan D. Harper (Dept. of Urology, Univ. of Washington School of Medicine, Seattle, WA), Barbrina Dunmire, Michael Bailey (Cntr.Industrial and Medical Ultrasound, Appl. Phys. Lab, Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, bailey@apl.washington.edu), Ziyue Liu (Dept. of Biostatistics, Indiana Univ. School of Medicine, Indianapolis, Washington), and Mathew D. Sorensen (Dept. of Urology, Dept. of Veteran Affairs Medical Ctr., Seattle, WA)

A pause early in shock wave lithotripsy (SWL) increased vasoconstriction as measured by resistive index (RI) during treatment and mitigated renal injury in an animal model. The purpose of our study was to investigate whether RI rose during SWL in humans. Prospectively recruited patients underwent SWL of renal stones with a Dornier Compact S lithotripter. The renal protective protocol consisted of treatment at 1 Hz and slow power ramping for the initial 250 shocks followed by a 2 min pause. RI was measured using ultrasound prior to treatment, after 250 shocks, after 750 shocks, after 1500 shocks, and after SWL. A linear mixed-effects model was used to compare RI at the different time points and to account for additional covariates in fifteen patients. RI was significantly higher than baseline for all time points 250 shocks and after. Age, gender, body mass index, and treatment side were not significantly associated with RI. Monitoring for a rise in RI during SWL is possible and may provide real-time feedback as to when the kidney is protected. [Work supported by NIH DK043881, NSBRI through NASA NCC 9-58, and resources from the VA Puget Sound Health Care System.]

9:15

3aBA6. Renal shock wave lithotripsy may be a risk factor for early-onset hypertension in metabolic syndrome: A pilot study in a porcine model. Rajash Handa (Anatomy & Cell Biology, Indiana Univ. School of Medicine, 635 Barnhill Dr., MS 5035, Indianapolis, IN 46202-5120, rhanda@iupui.edu), Ziyue Liu (Biostatistics, Indiana Univ. School of Medicine, Indianapolis, IN), Bret Connors, Cynthia Johnson, Andrew Evan (Anatomy & Cell Biology, Indiana Univ. School of Medicine, Indianapolis, IN), James Lingeman (Kidney Stone Inst., Indiana Univ. Health Methodist Hospital, Indianapolis, IN), David Basile, and Johnathan Tune (Cellular & Integrative Physiol., Indiana Univ. School of Medicine, Indianapolis, IN)

A pilot study was conducted to assess whether extracorporeal shock wave lithotripsy (SWL) treatment of the kidney influences the onset and severity of metabolic syndrome (MetS)—a cluster of conditions that includes central obesity, insulin resistance, impaired glucose tolerance, dyslipidemia, and hypertension. Methods: Three-month-old juvenile female Ossabaw miniature pigs were treated with either SWL (2000 SWs, 24 kV, 120 SWs/min using the HM3 lithotripter; n = 2) or sham-SWL (no SWs; n = 2). SWs were targeted to the upper pole of the left kidney so as to model treatment that would also expose the pancreas—an organ involved in blood glucose homeostasis—to SWs. The pigs were then instrumented for direct measurement of arterial blood pressure via implanted radiotelemetry devices, and later fed a hypercaloric atherogenic diet for ~7 months to induce MetS. The development of MetS was assessed from intravenous glucose tolerance tests. Results: The progression and severity of MetS were similar in the sham-treated and SWL-treated groups. The only exception was arterial blood pressure, which remained relatively constant in the sham-treated pigs and rose toward hypertensive levels in SW-treated pigs. Conclusions. These preliminary results suggest that renal SWL appears to be a risk factor for early-onset hypertension in MetS.

9:30–9:45 Break

9:45

3aBA7. Modeling vascular injury due to shock-induced bubble collapse in lithotripsy. Vedran Coralic and Tim Colonius (Mech. Eng., Caltech, 1200 E. California Blvd., Pasadena, CA 91125, colonius@caltech.edu)

Shock-induced collapse (SIC) of preexisting bubbles is investigated as a potential mechanism for vascular injury in shockwave lithotripsy (SWL). Preexisting bubbles exist under normal physiological conditions and grow larger and more numerous with ongoing treatment. We compute the three-dimensional SIC of a bubble using the multi-component Euler equations, and determine the resulting three-dimensional finite-strain deformation field in the material surrounding the collapsing bubble. We propose a criterion for vessel rupture and estimate the minimum bubble size, across clinical SWL pressures, which could result in rupture of microvasculature. Post-processing of the results and comparison to viscoelastic models for spherical bubble dynamics demonstrate that our results are insensitive to a wide range of estimated viscoelastic tissue properties during the collapse phase. During the jetting phase, however, viscoelastic effects are non-negligible. The minimum bubble size required to rupture a vessel is then estimated by adapting a previous model for the jet's penetration depth as a function of tissue viscosity.

10:00

3aBA8. Multiscale model of cavitation bubble formation and breakdown. Isaac Nault, Sorin M. Mitran (Mathematics, Univ. of North Carolina, CB3250, Chapel Hill, NC, naulti@live.unc.edu), Georgy Sankin, and Pei Zhong (Mech. Eng. and Mater. Sci., Duke Univ., Durham, NC)

Cavitation damage is responsible for initial pitting of kidney stone surfaces, damage that is thought to play an important role in shock wave lithotripsy. We introduce a multiscale model of the formation of cavitation bubbles in water, and subsequent breakdown. At a macroscopic, continuum scale cavitation is modeled by the 3D Euler equations with a Tait equation of state. Adaptive mesh refinement is used to provide increased resolution at the liquid/vapor boundary. Cells with both liquid and vapor phases are flagged by the continuum solver for mesoscale, kinetic modeling by a lattice Boltzmann description capable of capturing non-equilibrium behavior (e.g., phase change, energetic jet impingement). Isolated and interacting two-bubble configurations are studied. Computational simulation results are compared with high-speed experimental imaging of individual bubble dynamics and bubble–bubble interaction. The model is used to build a statistical description of multiple-bubble interaction, with input from cavitation cloud imaging. [Work supported by NIH through 5R37DK052985-18.]

10:15

3aBA9. Preliminary results of the feasibility to reposition kidney stones with ultrasound in humans. Jonathan D. Harper, Franklin Lee, Susan Ross, Hunter Wessells (Dept. of Urology, Univ. of Washington School of Medicine, Seattle, WA), Bryan W. Cunitz, Barbrina Dunmire, Michael Bailey (Ctr.Industrial and Medical Ultrasound, Appl. Phys. Lab, Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, bailey@apl.washington.edu), Jeff Thiel (Dept. of Radiology, Univ. of Washington School of Medicine, Seattle), Michael Coburn (Dept. of Urology, Baylor College of Medicine, Houston, TX), James E. Lingeman (Dept. of Urology, Indiana Univ. School of Medicine, Indianapolis, IN), and Mathew Sorensen (Dept. of Urology, Dept. of Veteran Affairs Medical Ctr., Seattle)

Preliminary investigational use of ultrasound to reposition human kidney stones is reported. The three study arms include: *de novo* stones, post-lithotripsy fragments, and large stones within the preoperative setting. A pain questionnaire is completed immediately prior to and following propulsion. A maximum of 40 push attempts are administered. Movement is classified as no motion, movement with rollback or jiggle, or movement to a new location. Seven subjects have been enrolled and undergone ultrasonic propulsion to date. Stones were identified, targeted, and moved in all subjects. Subjects who did not have significant movement were in the *de novo* arm. None of the subjects reported pain associated with the treatment. One subject in the post-lithotripsy arm passed two small stones immediately following treatment corresponding to the two stones displaced from the interpolar region. Three post-lithotripsy subjects reported passage of multiple small fragments within two weeks of treatment. In four subjects, ultrasonic

propulsion identified a collection of stones previously characterized as a single stone on KUB and ultrasound. There have been no treatment related adverse events reported with mean follow-up of 3 months. [Trial supported by NSBRI through NASA NCC 9-58. Development supported by NIH DK043881and DK092197.]

10:30

3aBA10. Nonlinear saturation effects in ultrasound fields of diagnostic-type transducers used for kidney stone propulsion. Maria M. Karzova (Phys. Faculty, Dept. of Acoust., M.V. Lomonosov Moscow State Univ., Leninskie Gory 1/2, Moscow 119991, Russian Federation, masha@acs366.phys.msu.ru), Bryan W. Cunitz (Ctr. for Industrial and Medical Ultrasound, Appl. Phys. Lab., Univ. of Washington, Seattle, WA), Petr V. Yuldashev (Phys. Faculty, M.V. Lomonosov Moscow State Univ., Moscow, Russian Federation), Vera A. Khokhlova, Wayne Kreider (Ctr. for Industrial and Medical Ultrasound, Appl. Phys. Lab., Univ. of Washington, Seattle, WA), Oleg A. Sapozhnikov (Phys. Faculty, M.V. Lomonosov Moscow State Univ., Moscow, Russian Federation), and Michael R. Bailey (Dept. of Urology, Univ. of Washington Medical Ctr., Seattle, WA)

A novel therapeutic application of ultrasound for repositioning kidney stones is being developed. The method uses acoustic radiation force to expel mm-sized stones or to dislodge even larger obstructing stones. A standard diagnostic 2.3 MHz C5-2 array probe has been used to generate pushing acoustic pulses. The probe comprises 128 elements equally spaced at the 55 mm long convex cylindrical surface with 41.2 mm radius of curvature. The efficacy of the treatment can be increased by using higher transducer output to provide stronger pushing force; however, nonlinear acoustic saturation effect can be a limiting factor. In this work, nonlinear propagation effects were analyzed for the C5-2 transducer using a combined measurement and modeling approach. Simulations were based on the 3D Westervelt equation; the boundary condition was set to match low power measurements. Focal waveforms simulated for several output power levels were compared with the fiber-optic hydrophone measurements and were found in good agreement. It was shown that saturation effects do limit the acoustic pressure in the focal region of the transducer. This work has application to standard diagnostic probes and imaging. [Work supported by RSF 14-12-00974, NIH EB007643, DK43881 and DK092197, and NSBRI through NASA NCC 9-58.]

10:45

3aBA11. Evaluating kidney stone size in children using the posterior acoustic shadow. Franklin C. Lee, Jonathan D. Harper, Thomas S. Lendvay (Urology, Univ. of Washington, Seattle, WA), Ziyue Liu (Biostatistics, Indiana Univ. School of Medicine , Indianapolis, IN), Barbrina Dunmire (Appl. Phys. Lab, Univ. of Washington, 1013 NE 40th St, Seattle, WA 98105, mrbean@uw.edu), Manjiri Dighe (Radiology, Univ. of Washington, Seattle, WA), Michael R. Bailey (Appl. Phys. Lab, Univ. of Washington, Seattle, WA), and Mathew D. Sorensen (Urology, Dept. of Veteran Affairs Medical Ctr., Seattle, WA)

Ultrasound, not x-ray, is preferred for imaging kidney stones in children; however, stone size determination is less accurate with ultrasound. *In vitro* we found stone sizing was improved by measuring the width of the acoustic shadow behind the stone. We sought to determine the prevalence and accuracy of the acoustic shadow in pediatric patients. A retrospective analysis was performed of all initial stone events at a children's hospital over the last 10 years. Included subjects had a computed tomography (CT) scan and renal ultrasound within 3 months of each other. The width of the stone and acoustic shadow were measured on ultrasound and compared to the stone size as determined by CT. Thirty-seven patients with 49 kidney stones were included. An acoustic shadow was seen in 85% of stones evaluated. Stone width resulted in an average overestimation of 1.2 ± 2.2 mm while shadow width resulted in an underestimation of 0.5 ± 1.7 mm ($p < 0.001$). A posterior acoustic shadow was seen in the majority of stones and was a more accurate measure of stone size. This would provide valuable information for stone management. [Work supported by NIH DK43881 and DK092197, and NSBRI through NASA NCC 9-58.]

11:00

3aBA12. Development and testing of an image-guided prototype system for the comminution of kidney stones using burst wave lithotripsy. Bryan Cunitz (Appl. Phys. Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, bwc@apl.washington.edu), Adam Maxwell (Dept. of Urology, Univ. of Washington Medical Ctr., Seattle, WA), Wayne Kreider, Oleg Sapozhnikov (Appl. Phys. Lab, Univ. of Washington, Seattle, WA), Franklin Lee, Jonathan Harper, Matthew Sorenson (Dept. of Urology, Univ. of Washington Medical Ctr., Seattle, WA), and Michael Bailey (Appl. Phys. Lab, Univ. of Washington, Seattle, WA)

Burst wave lithotripsy is a novel technology that uses focused, sinusoidal bursts of ultrasound to fragment kidney stones. Prior research laid the groundwork to design an extracorporeal, image-guided probe for *in-vivo* testing and potentially human clinical testing. Toward this end, a 12-element 330 kHz array transducer was designed and built. The probe frequency, geometry, and shape were designed to break stones up to 1 cm in diameter into fragments <2mm. A custom amplifier capable of generating output bursts up to 3 kV was built to drive the array. To facilitate image guidance, the transducer array was designed with a central hole to accommodate co-axial attachment of an HDI P4-2 probe. Custom B-mode and Doppler imaging sequences were developed and synchronized on a Verasonics ultrasound engine to enable real-time stone targeting and cavitation detection, Preliminary data suggest that natural stones will exhibit Doppler "twinkling" artifact in the BWL focus and that the Doppler power increases as the stone begins to fragment. This feedback allows accurate stone targeting while both types of imaging sequences can also detect cavitation in bulk tissue that may lead to injury. [Work supported by NIH grants DK043881, EB007643, EB016118, T32 DK007779, and NSBRI through NASA NCC 9-58.]

11:15

3aBA13. Removal of residual bubble nuclei to enhance histotripsy kidney stone erosion at high rate. Alexander P. Duryea (Biomedical Eng., Univ. of Michigan, 2131 Gerstacker Bldg., 2200 Bonisteel Blvd., Ann Arbor, MI 48109, duryalex@umich.edu), William W. Roberts (Urology, Univ. of Michigan, Ann Arbor, MI), Charles A. Cain, and Timothy L. Hall (Biomedical Eng., Univ. of Michigan, Ann Arbor, MI)

Previous work has shown that histotripsy can effectively erode model kidney stones to tiny, sub-millimeter debris via a cavitational bubble cloud localized on the stone surface. Similar to shock wave lithotripsy, histotripsy stone treatment displays a rate-dependent efficacy, with pulses applied at low repetition frequency producing more efficient erosion compared to those applied at high repetition frequency. This is attributed to microscopic residual cavitation bubble nuclei that can persist for hundreds of milliseconds following bubble cloud collapse. To mitigate this effect, we have developed low amplitude (MI<1) acoustic pulses to actively remove residual nuclei from the field. These bubble removal pulses utilize the Bjerknes forces to stimulate the aggregation and subsequent coalescence of remnant nuclei, consolidating the population from a very large number to a countably small number of remnant bubbles within several milliseconds. Incorporation of this bubble removal scheme in histotripsy model stone treatments performed at high rate (100 pulses/second) produced drastic improvement in treatment efficiency, with an average erosion rate increase of 12-fold in comparison to treatment without bubble removal. High speed imaging indicates that the influence of remnant nuclei on the location of bubble cloud collapse is the dominant contributor to this disparity in treatment efficacy.

Session 3aEA

Engineering Acoustics and Structural Acoustics and Vibration: Mechanics of Continuous Media

Andrew J. Hull, Cochair
Naval Undersea Warfare Center, 1176 Howell St, Newport, RI 02841

J. Gregory McDaniel, Cochair
Mechanical Engineering, Boston Univ., 110 Cummington St., Boston, MA 02215

Invited Papers

8:00

3aEA1. Fundamental studies of zero Poisson ratio metamaterials. Elizabeth A. Magliula (Div. Newport, Naval Undersea Warfare Ctr., 1176 Howell St., Bldg. 1302, Newport, RI 02841, elizabeth.magliula@navy.mil), J. Gregory McDaniel, and Andrew Wixom (Mech. Eng. Dept., Boston Univ., Boston, MA)

As material fabrication advances, new materials with special properties will be possible to accommodate new design boundaries. An emerging and promising field of investigation is to study the basic phenomena of materials with a negative Poisson ratio (NPR). This work seeks to develop zero Poisson ratio (ZPR) metamaterials for use in reducing acoustic radiation from compressional waves. Such a material would neither contract or expand laterally when compressed or stretched, and therefore not radiate sound. Previous work has provided procedures for creating NPR copper foam through transformation of the foam cell structure from a convex polyhedral shape to a concave "re-entrant" shape. A ZPR composite will be developed and analyzed in an effort to achieve desired wave propagation characteristics. Dynamic investigations have been conducted using ABAQUS, in which a ZPR is placed under load to observe displacement behavior. Inspection of the results at 1 kHz and 5 kHz show that the top and bottom surfaces experience much less displacement compared to respective conventional reference layer build-ups. However, at 11 kHz small lateral displacements were experienced at the outer surfaces. Results indicate that the net zero Poisson effect was successfully achieved at frequencies where half the wavelength is greater than the thickness.

8:20

3aEA2. Scattering by targets buried in elastic sediment. Angie Sarkissian, Saikat Dey, Brian H. Houston (Code 7130, Naval Res. Lab., Code 7132, 4555 Overlook Ave. S.W., Washington, DC 20375, angie.sarkissian@nrl.navy.mil), and Joseph A. Bucaro (Excet, Inc., Springfield, VA)

Scattering results are presented for targets of various shapes buried in elastic sediment with a plane wave incident from air above. The STARS3D finite element program recently extended to layered, elastic sediments is used to compute the displacement field just below the interface. Evidence of the presence of Rayleigh waves is observed in the elastic sediment and an algorithm based on the Rayleigh waves subtracts the contribution of the Rayleigh waves to simplify the resultant scattering pattern. Results are presented for scatterers buried in uniform elastic media as well as layered media. [This work was supported by ONR.]

8:40

3aEA3. Response shaping and scale transition in dynamic systems with arrays of attachments. Joseph F. Vignola, Aldo A. Glean (Mech. Eng., The Catholic Univ. of America, 620 Michigan Ave., NE, Washington, DC 20064, vignola@cua.edu), John Sterling (Carderock Div., Naval Surface Warfare Ctr., West Bethesda, MD), and John A. Judge (Mech. Eng., The Catholic Univ. of America, Washington, DC)

Arrays of elastic attachments can be design to act as energy sinks in dynamic systems. This presentation describes design strategies for drawing off mechanical energy to achieve specific objectives such as mode suppression and response tailoring in both extended and discrete systems. The design parameters are established using numerical simulations for both propagating and standing compressional waves in a one-dimensional system. The attachments were chosen to be cantilevers so that higher modes would have limited interaction with the higher modes of the primary structure. The two cases considered here are concentrated groups of cantilevers and spatial distributions of similar cantilevers. Relationships between the number and placement of the attachments and their masses and frequency distributions are of particular interest, along with the energy density distribution between the primary structure and the attachments. The simulations are also used to show how fabrication error degrades performance and how energy scale transition can be managed to maintain linear behavior.

9:00

3aEA4. Accelerated general method for computing noise effects in arrays. Heather Reed, Jeffrey Cipolla, Mahesh Bailakanavar, and Patrick Murray (Weidlinger Assoc., 40 Wall St 18th Fl., New York, NY 10005, heather.reed@wai.com)

Noise in an acoustic array can be defined as any unwanted signal, and understanding how noise interacts with a structural system is paramount for optimal design. For example, in an underwater vehicle we may want to understand how structural vibrations radiate through a surrounding fluid; or an engineer may want to evaluate the level of sound inside a car resulting from the turbulent boundary layer (TBL) induced by a moving vehicle. This talk will discuss a means of modeling noise at a point of interest (e.g., at a sensor location) stemming from a known source by utilizing a power transfer function between the source and the point of interest, a generalization of the work presented in [1]. The power transfer function can be readily computed from the acoustic response to an incident wave field, requiring virtually no additional computation. The acoustic solution may be determined via analytic frequency domain approaches or through a finite element analysis, enabling the noise solution to be a fast post processing exercise. This method is demonstrated by modeling the effects of a TBL pressure and noise induced by structural vibrations on a sensor array embedded in an elastic, multi-layer solid. Additionally, uncertainties in the noise model can be easily quantified through Monte Carlo techniques due to the fast evaluation of the noise spectrum. Ko, S.H. and Schloemer, H.H. "Flow noise reduction techniques for a planar array of hydrophones," J. Acoust. Soc. Am. 92, 3409 (1992).

9:20

3aEA5. Response of distributed fiber optic sensor cables to spherical wave incidence. Jeffrey Boisvert (NAVSEA Div. Newport, 1176 Howell St., Newport, RI 02841, cboisvertj@cox.net)

A generalized multi-layered infinite-length fiber optic cable is modeled using the exact theory of three-dimensional elasticity in cylindrical coordinates. A cable is typically composed of a fiber optic (glass) core surrounded by various layered materials such as plastics, metals, and elastomers. The cable is excited by an acoustic spherical wave radiated by a monopole source at an arbitrary location in the acoustic field. For a given source location and frequency, the radial and axial strains within the cable are integrated over a desired sensor zone length to determine the optical phase sensitivity using an equation that relates the strain distribution in an optical fiber to changes in the phase of an optical signal. Directivity results for the cable in a free-field water environment are presented at several frequencies for various monopole source locations. Some comparisons of the sensor directional response resulting from nearfield (spherical wave) incidence and farfield (plane wave) incidence are made. [Work supported by NAVSEA Division Newport ILIR Program.]

9:40

3aEA6. Testing facility concepts for the material characterization of porous media consisting of relatively limp foam and stiff fluid. Michael Woodworth and Jeffrey Cipolla (ASI, Weidlinger Assoc., Inc., 1825 K St NW, #350, Washington, DC 20006, michael.woodworth@wai.com)

Fluid filled foams are important components of acoustical systems. Most are made up of a stiff skeleton medium relative to the fluid considered, usually air. Biot's theory of poroelasticity is appropriate for characterizing and modeling these foams. The use of relatively stiff fluid (such as water) and limp foam media pose a greater challenge. Recently modifications to Biot's theory have generated the mechanical relationships required to model these systems. Necessary static material properties for the model can be obtain through *in vacuo* measurement. Frequency dependent properties are more difficult to obtain. Traditional impedance tube methods suffer from fluid structure interaction when the bulk modulus of the fluid media approaches that of the waveguide. The current investigation derives the theory for, and investigates the feasibility of, several rigid impedance tube alternatives for characterizing limp foams in stiff fluid media. Alternatives considered include a sufficiently rigid impedance tube, a pressure relief impedance tube and, the most promising, a piston excited oscillating chamber of small aspect ratio. The chamber concept can recover the descriptive properties of a porous medium described by Biot's theory or by complex-impedance equivalent-fluid models. The advantages of this facility are small facility size, low cost, and small sample size.

10:00–10:20 Break

10:20

3aEA7. Adomian decomposition identifies an approximate analytical solution for a set of coupled strings. David Segala (Naval Undersea Warfare Ctr., 1176 Howell St., Newport, RI 02841, david.segala@navy.mil)

The use of Adomian decomposition method (ADM) has been successfully applied in various applications across the applied mechanics and mathematics community. Originally, Adomian developed this method to derive analytical approximate solutions to nonlinear functional equations. It was shown that the solution to the given nonlinear functional equation can be approximated by an infinite series solution of the linear and nonlinear terms, provided the nonlinear terms are represented by a sum of series of Adomian polynomials. Here, ADM is used to derive an approximate analytical solution to a set of partial differential equations (PDEs) describing the motion of two coupled strings that lie orthogonal to each other. The PDEs are derived using Euler-Lagrange equations of motion. The ends of the strings are pinned and the strings are coupled with a nonlinear spring. A finite element model of the system is developed to provide a comparative baseline. Both the finite element model and analytical solution were driven by an initial displacement condition. The results from both the FEA and analytical solution were compared at six different equally spaced time points over the course of a 1.2 second simulation.

10:40

3aEA8. Comprehensive and practical explorations of nonlinear energy harvesting from stochastic vibrations. Ryan L. Harne and Kon-Well Wang (Mech. Eng., Univ. of Michigan, 2350 Hayward St., 2250 GG Brown Bldg., Ann Arbor, MI 48109-2125, rharne@umich.edu)

Conversion of ambient vibrational energies to electrical power is a recent, popular motivation for research that seeks to realize self-sustaining electronic systems including biomedical implants and remote wireless structural sensors. Many vibration resources are stochastic with spectra concentrated at extremely low frequencies, which is a challenging bandwidth to target in the design of compact, resonant electromechanical harvesters. Exploitation of design-based nonlinearities has uncovered means to reduce and broaden a harvester's frequency range of greatest sensitivity to be more compatible with ambient spectra, thus dramatically improving energy conversion performance. However, studies to date draw differing conclusions regarding the viability of the most promising nonlinear harvesters, namely, those designed around the elastic stability limit, although the investigations present findings having limited verification. To help resolve the outstanding questions about energy harvesting from stochastic vibrations using systems designed near the elastic stability limit, this research integrates rigorous analytical, numerical, and experimental explorations. The harvester architecture considered is a cantilever beam, which is the common focus of contemporary studies, and evaluates critical, practical factors involved for its effective implementation. From the investigations, the most favorable incorporations of nonlinearity are identified and useful design guidelines are proposed.

11:00

3aEA9. Response of infinite length bars and beams with periodically varying area. Andrew J. Hull and Benjamin A. Cray (Naval Undersea Warfare Ctr., 1176 Howell St., Newport, RI 02841, andrew.hull@navy.mil)

This talk develops a solution method for the longitudinal motion of a rod or the flexural motion of a beam of infinite length whose area varies periodically. The conventional rod or beam equation of motion is used with the area and moment of inertia expressed using analytical functions of the longitudinal (horizontal) spatial variable. The displacement field is written as a series expansion using a periodic form for the horizontal wavenumber. The area and moment of inertia expressions are each expanded into a Fourier series. These are inserted into the differential equations of motion and the resulting algebraic equations are orthogonalized to produce a matrix equation whose solution provides the unknown wave propagation coefficients, thus yielding the displacement of the system. An example problem of both a rod and beam are analyzed for three different geometrical shapes. The solutions to both problems are compared to results from finite element analysis for validation. Dispersion curves of the systems are shown graphically. Convergence of the series solutions is illustrated and discussed.

Contributed Papers

11:20

3aEA10. On the exact analytical solutions to equations of nonlinear acoustics. Alexander I. Kozlov (Medical and biological Phys., Vitebsk State Medical Univ., 27, Frunze Ave., Vitebsk 210023, Belarus, albapasserby@yahoo.com)

Some different equations derived as second-order approximations to complete system of equations of nonlinear acoustics of Newtonian media (such as Lighthill-Westerwelt equation, Kuznetsov one, etc.) are usually solved numerically or at least approximately. A general exact analytical method of solution of these problems based on a short chain of changes of variables is presented in the work. It is shown that neither traveling-wave solutions nor classical soliton-like solutions obey these equations. There are three types of possible forms of acoustical pressure depending on parameters of initial equation: so-called continuous shock (or diffusive soliton), a monotonously decaying solution as well as a sectionally continuous periodic one. Obtained results are in good qualitative agreement with previously published numerical calculations of different authors.

11:35

3aEA11. A longitudinal shear wave and transverse compressional wave in solids. ali Zorgani (LabTAU, INSERM, Univ. of Lyon, Bron, France), Stefan Catheline (LabTAU, INSERM, Univ. of Lyon, 151 Cours Albert Thomas, Lyon, France, stefan.catheline@inserm.fr), and Nicolas Benech (Instituto de fisica, Facultad de ciencia, Montevideo, Uruguay)

What general definition can one give to elastic P- and S-wave, especially when they are transversely and longitudinally polarized respectively? This question is the main motivation of the analysis of the Green's function reported in this letter. By separating the Green's function in a divergence free and a rotational free terms, not only a longitudinal S-wave but also a transversal P-wave are described. These waves are shown to be parts of the solution of the wave equation known as coupling terms. Similarly to surface water wave, they are divergence and rotational free. Their special motion is carefully described and illustrated.

Session 3aID

Student Council, Education in Acoustics and Acoustical Oceanography: Graduate Studies in Acoustics (Poster Session)

Zhao Peng, Cochair
Durham School of Architectural Engineering and Construction, University of Nebraska-Lincoln, 1110 S. 67th Street, Omaha, NE 68182

Preston S. Wilson, Cochair
Mech. Eng., The University of Texas at Austin, 1 University Station, C2200, Austin, TX 78712

Whitney L. Coyle, Cochair
The Pennsylvania State University, 201 Applied Science Building, University Park, PA 16802

All posters will be on display from 9:00 a.m. to 11:00 a.m. 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 10:00 a.m. and contributors of even-numbered papers will be at their posters from 10:00 a.m. to 11:00 a.m.

Invited Papers

3aID1. The Graduate Program in Acoustics at The Pennsylvania State University. Victor Sparrow and Daniel A. Russell (Grad. Prog. Acoust., Penn State, 201 Appl. Sci. Bldg., University Park, PA 16802, vws1@psu.edu)

In 2015, the Graduate Program in Acoustics at Penn State will be celebrating 50 years as the only program in the United States offering the Ph.D. in Acoustics as well as M.S. and M.Eng. degrees in Acoustics. An interdisciplinary program with faculty from a variety of academic disciplines, the Acoustics Program is administratively aligned with the College of Engineering and closely affiliated with the Applied Research Laboratory. The research areas include: ocean acoustics, structural acoustics, signal processing, aeroacoustics, thermoacoustics, architectural acoustics, transducers, computational acoustics, nonlinear acoustics, marine bioacoustics, noise and vibration control, and psychoacoustics. The course offerings include fundamentals of acoustics and vibration, electroacoustic transducers, signal processing, acoustics in fluid media, sound-structure interaction, digital signal processing, experimental techniques, acoustic measurements and data analysis, ocean acoustics, architectural acoustics, noise control engineering, nonlinear acoustics, ultrasonic NDE, outdoor sound propagation, computational acoustics, flow induced noise, spatial sound and 3D audio, marine bioacoustics, and the acoustics of musical instruments. Penn State Acoustics graduates serve widely throughout military and government labs, academic institutions, consulting firms, and industry. This poster will summarize faculty, research areas, facilities, student demographics, successful graduates, and recent enrollment and employment trends.

3aID2. Graduate studies in acoustics and noise control in the School of Mechanical Engineering at Purdue University. Patricia Davies, J. Stuart Bolton, and Kai Ming Li (Ray W. Herrick Labs., School of Mech. Eng., Purdue Univ., 177 South Russell St., West Lafayette, IN 47907-2099, daviesp@purdue.edu)

The acoustics community at Purdue University will be described with special emphasis on the graduate program in Mechanical Engineering (ME). Purdue is home to around 30 faculty who study various aspects of acoustics and related disciplines, and so, there are many classes to choose from as graduate students structure their plans of study to complement their research activities and to broaden their understanding of the various aspects of acoustics. In Mechanical Engineering, the primary emphasis is on understanding noise generation, noise propagation, and the impact of noise on people, as well as development of noise control strategies, experimental techniques, and noise and noise impact prediction tools. The ME acoustics research is conducted at the Ray W. Herrick Laboratories, which houses several large acoustics chambers that are designed to facilitate testing of a wide array mechanical systems, reflecting the Laboratories' long history of industry-relevant research. Complementing the acoustics research, Purdue has vibrations, dynamics, and electromechanical systems research programs and is home to a collaborative group of engineering and psychology professors who study human perception and its integration into engineering design. There are also very strong ties between ME acoustics faculty and faculty in Biomedical Engineering and Speech Language and Hearing Sciences.

3aID3. Acoustics program at the University of Rhode Island. Gopu R. Potty, James H. Miller, Brenton Wallin (Dept. of Ocean Eng., Univ. of Rhode Island, 115 Middleton Bldg., Narragansett, RI 02882, potty@egr.uri.edu), Charles E. White (Naval Undersea Warfare Ctr., Newport, RI), and Jennifer Giard (Marine Acoust., Inc., Middletown, RI)

The undergraduate and graduate program in Ocean Engineering at the University of Rhode Island is one of the oldest such programs in the United States. This program offers Bachelors, Masters (thesis and non-thesis options), and Ph.D. degrees in Ocean Engineering. The Ocean Engineering program has a strong acoustic component both at the undergraduate and graduate level. At the graduate level, students can specialize in several areas including geoacoustic inversion, propagation modeling, marine mammal acoustics, ocean

acoustic instrumentation, transducers, etc. Current acoustics related research activities of various groups will be presented. Information regarding the requirements of entry into the program will be provided. Many graduates from the program hold faculty positions at a number of universities in the United States and abroad. In addition, graduates from the ocean acoustics program at URI are key staff at many companies and organizations. The opportunities and challenges facing the program will be summarized.

3aID4. Graduate education and research in architectural acoustics at Rensselaer Polytechnic Institute. Ning Xiang, Jonas Braasch, and Todd Brooks (Graduate Program in Architectural Acoust., School of Architecture, Rensselaer Polytechnic Inst., Troy, NY 12180, xiangn@rpi.edu)

The rapid pace of change in the fields of architectural-, physical-, and psycho-acoustics has constantly advanced the Graduate Program in Architectural Acoustics from its inception in 1998 with an ambitious mission of educating future experts and leaders in architectural acoustics. Recent years we have reshaped its pedagogy using "STEM" (science, technology, engineering, and mathematics) methods, including intensive, integrative hands-on experimental components that fuse theory and practice in a collaborative environment. Our pedagogy enables graduate students from a broad range of fields to succeed in this rapidly changing field. The graduate program has attracted graduate students from a variety of disciplines including individuals with B.S., B.A., or B.Arch. degrees in Engineering, Physics, Mathematics, Computer Science, Electronic Media, Sound Recording, Music, Architecture, and related fields. RPI's Graduate Program in Architectural Acoustics has since graduated more than 100 graduates with both M.S. and Ph.D. degrees. Along with faculty members they have also actively 0contributed to the program's research in architectural acoustics, psychoaoustics, communication acoustics, signal processing in acoustics as well as our scientific exploration at the intersection of cutting edge research and traditional architecture/music culture. This paper shares the growth and evolution of the graduate program.

3aID5. Graduate training opportunities in the hearing sciences at the University of Louisville. Pavel Zahorik, Jill E. Preminger (Div. of Communicative Disord., Dept. of Surgery, Univ. of Louisville School of Medicine, Psychol. and Brain Sci., Life Sci. Bldg. 317, Louisville, KY 40292, pavel.zahorik@louisville.edu), and Christian E. Stilp (Dept. of Psychol. and Brain Sci., Univ. of Louisville, Louisville, KY)

The University of Louisville currently offers two branches of training opportunities for students interested in pursuing graduate training in the hearing sciences: A Ph.D. degree in experimental psychology with concentration in hearing science, and a clinical doctorate in audiology (Au.D.). The Ph.D. degree program offers mentored research training in areas such as psychoacoustics, speech perception, spatial hearing, and multisensory perception, and guarantees students four years of funding (tuition plus stipend). The Au.D. program is a 4-year program designed to provide students with the academic and clinical background necessary to enter audiologic practice. Both programs are affiliated with the Heuser Hearing Institute, which, along with the University of Louisville, provides laboratory facilities and clinical populations for both research and training. An accelerated Au.D./Ph.D. training program that integrates key components of both programs for training of students interested in clinically based research is under development. Additional information is available at http://louisville.edu/medicine/degrees/audiology and http://louisville.edu/psychology/graduate/vision-hearing.

3aID6. Graduate studies in acoustics, Speech and Hearing at the University of South Florida, Department of Communication Sciences and Disorders. Catherine L. Rogers (Dept. of Commun. Sci. and Disord., Univ. of South Florida, USF, 4202 E. Fowler Ave., PCD1017, Tampa, FL 33620, crogers2@usf.edu)

This poster will provide an overview of programs and opportunities for students who are interested in learning more about graduate studies in the Department of Communication Sciences and Disorders at the University of South Florida. Ours is a large and active department, offering students the opportunity to pursue either basic or applied research in a variety of areas. Current strengths of the research faculty in the technical areas of Speech Communication and Psychological and Physiological Acoustics include the following: second-language speech perception and production, aging, hearing loss and speech perception, auditory physiology, and voice acoustics and voice quality. Entrance requirements and opportunities for involvement in student research and professional organizations will also be described.

3aID7. Graduate programs in Hearing and Speech Sciences at Vanderbilt University. G. Christopher Stecker and Anna C. Diedesch (Hearing and Speech Sci., Vanderbilt Univ. Medical Ctr., 1215 21st Ave. South, Rm. 8310, Nashville, TN 37232-8242, g.christopher.stecker@vanderbilt.edu)

The Department of Hearing and Speech Sciences at Vanderbilt University is home to several graduate programs in the areas of Psychological and Physiological Acoustics and Speech Communication. Programs include the Ph.D. in Audiology, Speech-Language Pathology, and Hearing or Speech Science, Doctor of Audiology (Au.D.), and Master's programs in Speech-Language Pathology and Education of the Deaf. The department is closely affiliated with Vanderbilt University's Graduate Program in Neurobiology. Several unique aspects of the research and training environment in the department provide exceptional opportunities for students interested in studying the basic science as well as clinical-translational aspects of auditory function and speech communication in complex environments. These include anechoic and reverberation chambers capable of multichannel presentation, the Dan Maddox Hearing Aid Laboratory, and close connections to active Audiology, Speech-Pathology, Voice, and Otolaryngology clinics. Students interested in the neuroscience of communication utilize laboratories for auditory and multisensory neurophysiology and neuroanatomy, human electrophysiology and neuroimaging housed within the department and at the neighboring Vanderbilt University Institute for Imaging Science. Finally, department faculty and students engage in numerous engineering and industrial collaborations, which benefit from our home within Vanderbilt University and setting in Music City, Nashville. Tennessee.

3aID8. Underwater acoustics graduate study at the Applied Physics Laboratory, University of Washington. Robert I. Odom (Appl. Phys. Lab, Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, odom@apl.washington.edu)

With faculty representation in the Departments of Electrical Engineering, and Mechanical Engineering within the College of Engineering, the School of Oceanography, and the Department of Earth and Space Sciences within the College of the Environment, underwater acoustics at APL-UW touches on topics as diverse as long range controlled source acoustics, very low frequency seismics, sediment acoustics, marine mammal vocalizations, and noise generated by industrial activities such as pile driving, among other things. Graduate studies leading to both M.S. and Ph.D. degrees are available. Examples of projects currently being pursued and student opportunities are highlighted in this poster.

3aID9. Graduate acoustics at Brigham Young University. Timothy W. Leishman, Kent L. Gee, Tracianne B. Neilsen, Scott D. Sommerfeldt, Jonathan D. Blotter, and William J. Strong (Brigham Young Univ., N311 ESC, Provo, UT 84602, tbn@byu.edu)

Graduate studies in acoustics at Brigham Young University prepare students for jobs in industry, research, and academia by complementing in-depth coursework with publishable research. In the classroom, a series of five graduate-level core courses provides students with a solid foundation in core acoustics principles and practices. The associated lab work is substantial and provides hands-on experience in diverse areas of acoustics: calibration, directivity, scattering, absorption, Doppler vibrometry, lumped-element mechanical systems, equivalent circuit modeling, arrays, filters, room acoustics measurements, active noise control, and near-field acoustical holography. In addition to coursework, graduate students complete independent research projects with faculty members. Recent thesis and dissertation topics have included active noise control, directivity of acoustic sources, room acoustics, radiation and directivity of musical instruments, energy-based acoustics, aeroacoustics, propagation modeling, nonlinear propagation, and high-amplitude noise analysis. In addition to their individual projects, graduate students often serve as peer mentors to undergraduate students on related projects and often participate in field experiments to gain additional experience. Students are expected to develop their communication skills, present their research at multiple professional meetings, and publish it in peer-reviewed acoustics journals. In the past five years, nearly all graduate students have published at least one refereed paper.

3aID10. Acoustics-related research in the Department of Speech and Hearing Sciences at Indiana University. Tessa Bent, Steven Lulich, Robert Withnell, and William Shofner (Dept. of Speech and Hearing Sci., Indiana Univ., 200 S. Jordan Ave., Bloomington, IN 47405, tbent@indiana.edu)

In the Department of Speech and Hearing Sciences at Indiana University, there are many highly active laboratories that conduct research on a wide range of areas in acoustics. Four of these laboratories are described below. The Biophysics Lab (PI: Robert Withnell) focuses on the mechanics of hearing. Acoustically based signal processing and data acquisition provide experimental data for model-based analysis of peripheral sound processing. The Comparative Perception Lab (PI: William Shofner) focuses on how the physical features of complex sounds are related to their perceptual attributes, particularly pitch and speech. Understanding behavior and perception in animals, particularly in chinchillas, is an essential component of the research. The Speech Production Laboratory (PI: Steven Lulich) conducts research on imaging of the tongue and oral cavity, speech breathing, and acoustic modeling of the whole vocal/respiratory tract. Laboratory equipment includes 3D/4D ultrasound, digitized palate impressions, whole-body and inductive plethysmography, electroglottography, oral and nasal pressure and flow recordings, and accelerometers. The Speech Perception Lab (PI: Tessa Bent) focuses on the perceptual consequences of phonetic variability in speech, particularly foreign-accented speech. The main topics under investigation are perceptual adaptation, individual differences in word recognition, and developmental speech perception.

3aID11. Biomedical research at the image-guided ultrasound therapeutics laboratories. Christy K. Holland (Internal Medicine, Univ. of Cincinnati, 231 Albert Sabin Way, CVC 3935, Cincinnati, OH 45267-0586, Christy.Holland@uc.edu), T. Douglas Mast (Biomedical Eng., Univ. of Cincinnati, Cincinnati, OH), Kevin J. Haworth, Kenneth B. Bader, Himanshu Shekhar, and Kirthi Radhakrishnan (Internal Medicine, Univ. of Cincinnati, Cincinnati, OH)

The Image-guided Ultrasound Therapeutic Laboratories (IgUTL) are located at the University of Cincinnati in the Heart, Lung, and Vascular Institute, a key component of efforts to align the UC College of Medicine and UC Health research, education, and clinical programs. These extramurally funded laboratories, directed by Prof. Christy K. Holland, are comprised of graduate and undergraduate students, postdoctoral fellows, principal investigators, and physician-scientists with backgrounds in physics and biomedical engineering, and clinical and scientific collaborators in fields including cardiology, neurosurgery, neurology, and emergency medicine. Prof. Holland's research focuses on biomedical ultrasound including sonothrombolysis, ultrasound-mediated drug and bioactive gas delivery, development of echogenic liposomes, early detection of cardiovascular diseases, and ultrasound-image guided tissue ablation. The Biomedical Ultrasonics and Cavitation Laboratory within IgUTL, directed by Prof. Kevin J. Haworth, employs ultrasound-triggered phase-shift emulsions (UPEs) for image-guided treatment of cardiovascular disease, especially thrombotic disease. Imaging algorithms incorporate both passive and active cavitation detection. The Biomedical Acoustics Laboratory within IgUTL, directed by Prof. T. Douglas Mast, employs ultrasound for monitoring thermal therapy, ablation of cancer and vascular targets, transdermal drug delivery, and noninvasive measurement of tissue deformation.

3aID12. Graduate acoustics education in the Cockrell School of Engineering at The University of Texas at Austin. Michael R. Haberman (Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX), Neal A. Hall (Elec. and Comp. Eng. Dept., The Univ. of Texas at Austin, Austin, TX), Mark F. Hamilton (Mech. Eng. Dept., The Univ. of Texas at Austin, 1 University Station, C2200, Austin, TX 78712), Marcia J. Isakson (Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX), and Preston S. Wilson (Mech. Eng. Dept., The Univ. of Texas at Austin, Austin, TX, pswilson@mail.utexas.edu)

While graduate study in acoustics takes place in several colleges and schools at The University of Texas at Austin (UT Austin), including Communication, Fine Arts, Geosciences, and Natural Sciences, this poster focuses on the acoustics program in Engineering. The core of this program resides in the Departments of Mechanical Engineering (ME) and Electrical and Computer Engineering (ECE). Acoustics faculty in each department supervise graduate students in both departments. One undergraduate and seven graduate acoustics courses are cross-listed in ME and ECE. Instructors for these courses include staff at Applied Research Laboratories at UT Austin, where many of the graduate students have research assistantships. The undergraduate course, taught every fall, begins with basic physical acoustics and proceeds to draw examples from different areas of engineering acoustics. Three of the graduate courses are taught every year: a two-course sequence on physical acoustics, and a transducers course. The remaining four graduate acoustics courses, taught in alternate years, are on nonlinear acoustics, underwater acoustics, ultrasonics, and architectural acoustics. An acoustics seminar is held most Fridays during the long semesters, averaging over ten per semester since 1984. The ME and ECE departments both offer Ph.D. qualifying exams in acoustics.

3aID13. Graduate studies in Ocean Acoustics in the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution Joint Program. Andone C. Lavery (Appl. Ocean Phys. and Eng., Woods Hole Oceanographic Inst., 98 Water St., MS 11, Bigelow 211, Woods Hole, MA 02536, alavery@whoi.edu)

An overview of graduate studies in Ocean Acoustics within the framework of the Massachusetts Institute of Technology (MIT) and Woods Hole Oceanographic Institution (WHOI) Joint Program is presented, including a brief history of the program, facilities, details of the courses offered, alumni placing, funding opportunities, and current program status, faculty members and research. Emphasis is given to the key role of the joint strengths provided by MIT and WHOI, the strong sea-going history of the program, and the potential for highly interdisciplinary research.

3aID14. Graduate studies in acoustics at the University of Notre Dame. Christopher Jasinski and Thomas C. Corke (Aerosp. and Mech. Eng., Univ. of Notre Dame, 54162 Ironwood Rd., South Bend, IN 46635, chrismjasinski@gmail.com)

The University of Notre Dame department of Aerospace and Mechanical Engineering is conducting cutting edge research in aeroacoustics, structural vibration, and wind turbine noise. Expanding facilities are housed at two buildings of the Hessert Laboratory for Aerospace Engineering and include two 25 kW wind turbines, a Mach 0.6 wind tunnel, and an anechoic wind tunnel. Several faculty members conduct research related to acoustics and multiple graduate level courses are offered in general acoustics and aeroacoustics. This poster presentation will give an overview of the current research activities, laboratory facilities, and graduate students and faculty involved at Notre Dame's Hessert Laboratory for Aerospace Engineering.

3aID15. Graduate study in Architectural Acoustics within the Durham School at the University of Nebraska—Lincoln. Lily M. Wang, Matthew G. Blevins, Zhao Peng, Hyun Hong, and Joonhee Lee (Durham School of Architectural Eng. and Construction, Univ. of Nebraska-Lincoln, 1110 South 67th St., Omaha, NE 68182-0816, lwang4@unl.edu)

Persons interested in pursuing graduate study in architectural acoustics are encouraged to consider joining the Architectural Engineering Program within the Durham School of Architectural Engineering and Construction at the University of Nebraska—Lincoln (UNL). Among the 21 ABET-accredited Architectural Engineering (AE) programs across the United States, the Durham School's program is one of the few that offers graduate engineering degree programs (MAE, MS, and PhD) and one of only two that offers an area of concentration in architectural acoustics. Acoustics students in the Durham School benefit both from the multidisciplinary environment in an AE program and from our particularly strong ties to the building industry, since three of the largest architectural engineering companies in the United States are headquartered in Omaha, Nebraska. Descriptions will be given on the graduate-level acoustics courses, newly renovated acoustic lab facilities, the research interests and achievements of our acoustics faculty and students, and where our graduates are to date. Our group is also active in extracurricular activities, particularly through the University of Nebraska Acoustical Society of America Student Chapter. More information on the "Nebraska Acoustics Group" at the Durham School may be found online at http://nebraskaacousticsgroup.org/.

3aID16. Pursuing the M.Eng. in acoustics through distance education from Penn State. Daniel A. Russell and Victor W. Sparrow (Graduate Program in Acoust., Penn State Univ., 201 Appl. Sci. Bldg, University Park, PA 16802, drussell@engr.psu.edu)

Since 1987, the Graduate Program in Acoustics at Penn State has been providing remote access to graduate level education leading to the M.Eng. degree in Acoustics. Course lecture content is currently broadcast as a live-stream via Adobe Connect to distance students scattered throughout North America and around the world, while archived recordings allow distance students to access lecture material at their convenience. Distance Education students earn the M.Eng. in Acoustics degree by completing 30 credits of coursework (six required core courses and four electives) and writing a capstone paper. Courses offered for distance education students include: fundamentals of acoustics and vibration, electroacoustic transducers, signal processing, acoustics in fluid media, sound and structure interaction, digital signal processing, aerodynamic noise, acoustic measurements and data analysis, ocean acoustics, architectural acoustics, noise control engineering, nonlinear acoustics, outdoor sound propagation, computational acoustics, flow induced noise, spatial sound

and 3D audio, marine bioacoustics, and acoustics of musical instruments. This poster will summarize the distance education experience leading to the M.Eng. degree in Acoustics from Penn State showcasing student demographics, capstone paper topics, enrollment statistics and trends, and the success of our graduates.

3aID17. Graduate studies in acoustics at Northwestern University. Ann Bradlow (Linguist, Northwestern Univ., 2016 Sheridan Rd., Evanston, IL IL, abradlow@northwestern.edu)

Northwestern University has a vibrant and highly interdisciplinary community of acousticians. Of the 13 ASA technical areas, three have strong representation at Northwestern: Speech Communication, Psychological and Physiological Acoustics, and Musical Acoustics. Sound-related work is conducted across a wide range of departments including Linguistics (in the Weinberg College of Arts and Sciences), Communication Sciences & Disorders, and Radio/Television/Film (both in the School of Communication), Electrical Engineering & Computer Science (in the McCormick School of Engineering), Music Theory & Cognition (in the Bienen School of Music), and Otolaryngology (in the Feinberg School of Medicine). In addition, The Knowles Hearing Center involves researchers and labs across the university dedicated to the prevention, diagnosis and treatment of hearing disorders. Specific acoustics research topics across the university range from speech perception and production across the lifespan and across languages, dialect and socio-indexical properties of speech, sound design, machine perception of music and audio, musical communication, the impact of long-term musical experience on auditory encoding and representation, auditory perceptual learning, and the cellular, molecular, and genetic bases of hearing function. We invite you to visit our poster to learn more about the "sonic boom" at Northwestern University!

WEDNESDAY MORNING, 29 OCTOBER 2014 SANTA FE, 9:00 A.M. TO 11:45 A.M.

Session 3aMU

Musical Acoustics: Topics in Musical Acoustics

Jack Dostal, Chair
Physics, Wake Forest University, P.O. Box 7507, Winston-Salem, NC 27109

Contributed Papers

9:00

3aMU1. Study of free reed attack transients using high speed video. Spencer Henessee (Phys., Coe College, GMU #447, 1220 First Ave. NE, Cedar Rapids, IA 52402, sahenessee@coe.edu), Daniel M. Wolff (Univ. of North Carolina at Greensboro, Greensboro, NC), and James P. Cottingham (Phys., Coe College, Cedar Rapids, IA)

Earlier methods of studying the motion of free reeds have been augmented with the use of high-speed video, resulting in a more detailed picture of reed oscillation, especially the initial transients. Displacement waveforms of selected points on the reed tongue image can be obtained using appropriate tracking software. The waveforms can be analyzed for the presence of higher modes of vibration and other features of interest in reed oscillation, and they can be used in conjunction with displacement or velocity waveforms obtained by other means, along with finite element simulations, to obtain detailed information about reed oscillation. The high speed video data has a number of advantages. It can provide a two-dimensional image of the motion of any point tracked on the reed tongue, and the freedom to change the points selected for tracking provides flexibility in data acquisition. In addition, the high speed camera is capable of simultaneous triggering of other motion sensors as well as oscilloscopes and spectrum analyzers. Some examples of the use of high speed video are presented and some difficulties in the use of this technique are discussed. [Work partially supported by US National Science Foundation REU Grant PHY-1004860.]

9:15

3aMU2. Detailed analysis of free reed initial transients. Daniel M. Wolff (Univ. of North Carolina at Greensboro, 211 McIver St. Apt. D, Greensboro, NC 27403, dmwolff@uncg.edu), Spencer Henessee, and James P. Cottingham (Phys., Coe College, Cedar Rapids, IA)

The motion of the reed tongue in early stages of the attack transient has been studied in some detail for reeds from a reed organ. Oscillation waveforms were obtained using a laser vibrometer system, variable impedance transducer proximity sensors, and high speed video with tracking software. Typically, the motion of the reed tongue begins with an initial displacement of the equilibrium position, often accompanied by a few cycles of irregular oscillation. This is followed by a short transitional period in which the amplitude of oscillation gradually increases and the frequency stabilizes at the steady state oscillation frequency. In the next stage, the amplitude of oscillation continues to increase to the steady state value. The spectra derived from the waveforms in each stage have been analyzed, showing that the second transverse mode and the first torsional mode are both observed in the transient, with the amplitude of the torsional mode apparently especially significant in the earlier stages of oscillation. Comparison of reed tongues of different design have been made to explore the role of the torsional mode the initial excitation. Finite element simulations have been used to aid in the verification and interpretation of some of the results. [Work supported by US National Science Foundation REU Grant PHY-1004860.]

9:30

3aMU3. Comparison of traditional and matched grips: Rhythmic sequences played in jazz drumming. E. K. Ellington Scott (Oberlin College, OCMR2639, Oberlin College, Oberlin, OH 44074, escott@oberlin.edu) and James P. Cottingham (Phys., Coe College, Cedar Rapids, IA)

Traditional and matched grips have been compared using a series of measurements involving rhythmic sequences played by experienced jazz drummers using each of the two grips. Rhythmic sequences played on the snare drum were analyzed using high speed video as well as other measurement techniques including laser vibrometry and spectral analysis of the sound waveforms. The high speed video images, used with tracking software, allow observation of several aspects of stick-drum head interaction. These include two-dimensional trajectories of the drum stick tip, a detailed picture of the stick-drum head interaction, and velocities of both the stick and the drum head during the contact phase of the stroke. Differences between the two grips in timing during the rhythmic sequences were investigated, and differences in sound spectrum were also analyzed. Some factors that may be player dependent have been explored, such as the effect of tightness of the grip, but an effort has been made to concentrate on factors that are independent of the player. [Work supported by US National Science Foundation REU Grant PHY-1004860.]

9:45

3aMU4. A harmonic analysis of oboe reeds. Julia Gjebic, Karen Gipson (Phys., Grand Valley State Univ., 10255 42nd Ave., Apt. 3212, Allendale, MI 49401, gjebicj@mail.gvsu.edu), and Marlen Vavrikova (Music and Dance, Grand Valley State Univ., Allendale, MI)

Because oboists make their own reeds to satisfy personal and physiological preferences, no two reed-makers construct their reeds in the same manner, just as no two oboe players have the same sound. The basic structure of an oboe reed consists of two curved blades of the grass Arundo donax bound to a conical metal tube (a staple) such that the edges of the blades meet and vibrate against one another when stimulated by a change in the surrounding pressure. While this basic structure is constant across reed-makers, the physical measurements of the various portions of the reed (tip, spine, and heart) resulting from the final stage of reed-making (scraping) can vary significantly between individual oboists. In this study, we investigated how the physical structure of individual reeds relates to the acoustic spectrum. We performed statistical analyses to discern which areas of the finished reed influence the harmonic series most strongly. This information is of great interest to oboists as it allows them quantitative insight into how their individual scrape affects their overall tone quality and timbre.

10:00

3aMU5. Modeling and numerical simulation of a harpsichord. Rossitza Piperkova, Sebastian Reiter, Martin Rupp, and Gabriel Wittum (Goethe Ctr. for Sci. Computing, Goethe Univ. Frankfurt, Kettenhofweg 139, Frankfurt am Main 60325, Germany, Wittum@gcsc.uni-frankfurt.de)

This research studies what influences various properties of a soundboard may have upon the acoustic feedback to gain a better understanding about the relevance of different properties regarding the sound characteristics. It may also help to improve the quality of simulations. We did a modal analysis of a real soundboard of a harpsichord using a Laser-Doppler-Vibrometer and also simulated several models of the very same soundboard in three space dimensions using the simulation software UG4. The used models of the sound board differed from each other by changing or skipping several properties and components. Then, we compared the simulated vibration patterns with the patterns measured on the real sound board to gain a better understanding about their influences on the vibrations. In particular, we used models with and without soundboard bars and bridge, but also were using different thicknesses for the soundboard itself.

10:15–10:30 Break

10:30

3aMU6. Temporal analysis, manipulation, and resynthesis of musical vibrato. Mingfeng Zhang, Gang Ren, Mark Bocko (Dept. Elec. and Comput. Eng., Univ. of Rochester, Rochester, NY 14627, mzhang43@hse.rochester.edu), and James Beauchamp (Dept. Elec. and Comput. Eng., Univ. of Illinois at Urbana–Champaign, Urbana, IL)

Vibrato is an important music performance technique for both voice and various music instruments. In this paper, a signal processing framework for vibrato analysis, manipulation and resynthesis is presented. In the analysis part, music vibrato is treated as a generalized descriptor of music timbre and the signal magnitude and instantaneous frequency is implemented as temporal features. Specifically, the magnitude track shows the dynamic variations of audio loudness, and the frequency track shows the frequency deviations varying with time. In the manipulation part, several manipulation methods for the magnitude track and the frequency track is implemented. The tracking results are manipulated in both the time- and the frequency-domain. These manipulation methods are implemented as an interactive process to allow musicians to manually adjust the processing parameters. In the resynthesis part, the simulated vibrato audio is created using sinusoidal resynthesis process. The resynthesis part serves three purpose: to imitate human music performance, to migrate sonic features across music performances, and to serve as creative audio design tools, e.g., to create non-existing vibrato characteristics. The source audio from human music performance and the resynthesize audio is compared using subjective listening tests to validate our proposed framework.

10:45

3aMU7. Shaping musical vibratos using multi-modal pedagogical interactions. Mingfeng Zhang, Fangyu Ke (Dept. Elec. and Comput. Eng., Univ. of Rochester, Rochester, NY 14627, mzhang43@hse.rochester.edu), James Beauchamp (Dept. Elec. and Comput. Eng., Univ. of Illinois at Urbana–Champaign, Urbana, IL), and Mark Bocko (Dept. Elec. and Comput. Eng., Univ. of Rochester, Rochester, NY)

The music vibrato is termed a "pulsation in pitch, intensity, and timbre" because of its effectiveness in artistic rendering. However, this sonic trick is largely still a challenge in music pedagogy across music conservatories. In classroom practice, music teachers use demonstration, body gestures, and metaphors to convey their artistic intentions and the modern computer tools are seldom employed. In our proposed framework, we use musical vibrato visualization and sonification tools as a multi-modal computer interface for pedagogical purpose. Specifically, we compare master performance audio with student performance audio using signal analysis tools. Then, we obtain various similarity measures based on these signal analysis results. Based on these similarity measures we implement multi-modal interactions for music students to shape their music learning process. The visualization interface is based on audio features including dynamics, pitch and timbre. The sonifications interface is based on recorded audio and synthesized audio. To enhance the music relevance of our proposed framework, both visualization and sonification tools are targeted to serve a musical communicating to convey musical concepts in an intuitive manner. The proposed framework is evaluation using subjective ratings from music students and objective assessment of measurable training goals.

11:00

3aMU8. Absolute memory for popular songs is predicted by auditory working memory ability. Stephen C. Van Hedger, Shannon L. Heald, Rachelle Koch, Howard C. Nusbaum (Psych., The Univ. of Chicago, 5848 S. University Ave., Beecher 406, Chicago, IL 60637, stephen.c.hedger@gmail.com),

While most individuals do not possess absolute pitch (AP)—the ability to name an isolated musical note in absence of a reference note—they do show some limited memory for absolute pitch of melodies. For example, most individuals are able to recognize when a well-known song has been subtly pitch shifted. Presumably, individuals are able to select the correct absolute pitch at above-chance levels because well-known songs are frequently heard at a consistent pitch. In the current studies, we ask whether individual differences in absolute pitch judgments for people without AP can be explained by general differences in auditory working memory.

Working memory capacity has been shown to predict the perceptual fidelity of long-term category representations in vision; thus, it is possible that auditory working memory capacity explains individual differences in recognizing the tuning of familiar songs. We found that participants were reliably above chance in classifying popular songs as belonging to the correct or incorrect key. Moreover, individual differences in this recognition performance were predicted by auditory working memory capacity, even after controlling for overall music experience and stimulus familiarity. Implications for the interaction between working memory and AP are discussed.

11:15

3aMU9. Constructing alto saxophone multiphonic space. Keith A. Moore (Music, Columbia Univ., 805 W Church St., Savoy, Illinois 10033, kam101@columbia.edu)

Multiphonics are sonorities with two or more independent tones arising from instruments, or portions of instruments, associated with the production of single pitches. Since the 1960s multiphonics have been probed in two ways. Acousticians have explored the role of nonlinearity in multiphonic sound production (Benade 1976; Backus 1978; Keefe & Laden 1991) and musicians have created instrumental catalogs of multiphonic sounds (Bartolozzi 1967; Rehfeldt 1977; Kientzy 1982; Levine 2002). These lines of inquiry have at times been combined (Veale & Mankopf 1994). However, a meta-level analysis has not yet emerged from this work that answers basic questions such as how many kinds of multiphonics are found on one particular instrument and which physical conditions underlie such variety. The present paper suggests a database driven approach to the problem, producing a "quantitative resonant frequency curve" that shows every audible appearance of each frequency in a large—if not permutationally exhaustive—set of alto saxophone multiphonics. Compelling data emerges, including sonority prototypes, prototype transposition levels, and register specific distortions. Notably, true difference tones—audible difference tones unsustainable apart from a sounding multiphonic—are found to be register specific, not sonority specific; suggesting that physical locations (rather than harmonic contexts) underpin these sounds.

11:30

3aMU10. Linear-response reflection coefficient of the recorder air-jet amplifier. John C. Price (Phys., Univ. of Colorado, 390 UCB, Boulder, CO 80309, john.price@colorado.edu), William Johnston (Phys., Colorado State Univ., Fort Collins, CO), and Daniel McKinnon (Chemical Eng., Univ. of Colorado, Boulder, CO)

Steady-state oscillations in a duct flute, such as the recorder, are controlled by (1) closing tone holes and (2) adjusting the blowing pressure or air-jet velocity. The acoustic amplitude in steady-state cannot be controlled independent of the jet velocity, because it is determined by the gain saturation properties of the air-jet amplifier. Consequently, the linear-response gain of the air-jet amplifier has only very rarely been studied [Thwaites and Fletcher, J. Acoust. Soc. Am. **74**, 400–408 (1983)]. Efforts have focused instead on the more complex gain-saturated behavior, which is controlled by vortex shedding at the labium. We replace the body of a Yamaha YRT-304B tenor recorder with a multi-microphone reflectometer and measure the complex reflection coefficient of the head at small acoustic amplitudes as a function of air-jet velocity and acoustic frequency. We find that the gain (reflection coefficient magnitude) has a maximum value of 2.5 at a Strouhal number of $\approx$0.3 (jet transit time divided by acoustic period), independent of jet velocity. Surprisingly, the frequency where the gain peaks for a given blowing pressure is not close to the in-tune pitch of a note that is played at the same blowing pressure.

WEDNESDAY MORNING, 29 OCTOBER 2014 — MARRIOTT 3/4, 8:45 A.M. TO 12:00 NOON

Session 3aNS

Noise and ASA Committee on Standards: Wind Turbine Noise

Nancy S. Timmerman, Cochair
Nancy S. Timmerman, P.E., 25 Upton Street, Boston, MA 02118

Robert D. Hellweg, Cochair
Hellweg Acoustics, 13 Pine Tree Rd., Wellesley, MA 02482

Paul D. Schomer, Cochair
Schomer and Associates Inc., 2117 Robert Drive, Champaign, IL 61821

Kenneth Kaliski, Cochair
RSG Inc., 55 Railroad Row, White River Junction, VT 05001

Invited Papers

8:45

3aNS1. Massachusetts Wind Turbine Acoustics Research Project—Goals and preliminary results. Kenneth Kaliski, David Lozupone (RSG Inc., 55 RailRd. Row, White River Junction, VT 05001, ken.kaliski@rsginc.com), Peter McPhee (Massachusetts Clean Energy Ctr., Boston, MA), Robert O'Neal (Epsilon Assoc., Maynard, MA), John Zimmerman (Northeast Wind, Waterbury, VT), Kieth Wilson (Keith Wilson, Hanover, NH), and Carol Rowan-West (Massachusetts Dept. of Environ. Protection, Boston, MA)

The Commonwealth of Massachusetts (USA) has 43 operating wind turbine projects of 100 kW or more. At several of these projects, noise complaints have been made to state authorities. The Massachusetts Clean Energy Center, which provides funding for early stage analysis and development of wind power projects, and the Massachusetts Department of Environmental Protection, which regulates noise, launched the project to increase understanding of (1) wind turbine acoustic impacts, taking into account variables such as wind turbine size, technology, wind speed, topography and distance, and (2) the generation, propagation, and measurement of sound around wind turbine projects, to inform policy-makers on how pre- and post-construction wind turbine noise studies should be conducted. This study involved the collection of detailed sound and meteorological data at five locations. The resulting database and interim reports contain information on infrasound and audible frequencies, including amplitude modulation, tonality, and level. Analyses will include how the effects of wind shear and other variables may affect these parameters. Preliminary findings reflect the effects of meteorological conditions on wind turbine sound generation and propagation.

9:05

3aNS2. Wind turbine annoyance—A clue from acoustic room modes. William K. Palmer (TRI-LEA-EM, 76 SideRd. 33-34 Saugeen, RR 5, Paisley, ON N0G2N0, Canada, trileaem@bmts.com)

When one admits that they do not know all the answers and sets out to listen to the stories of people annoyed by wind turbines, the clues can seem confusing. Why would some people report that they could get a better night's sleep in an outdoor tent, rather than their bedroom? Others reported that they could sleep better in the basement recreation room of their home, than in bedrooms. That made little sense either. A third mysterious clue came from acoustic measurements at homes nearby wind turbines. Analysis of the sound signature revealed low frequency spikes, but at amplitudes well below those expected to cause annoyance. The clues merged while studying the acoustic room modes in a home, to reveal a remarkable hypothesis as to the cause of annoyance from wind turbines. In rooms where annoyance was felt, the frequencies flagged by room mode calculations and the low frequency spikes observed from wind turbine measurements coincided. This paper will discuss the research and the results, which revealed a finding that provides a clue to the annoyance, and potentially even a manner of providing limited relief.

9:25

3aNS3. A perspective on wind farm complaints and the Acoustical Society of America's public policy. Paul D. Schomer (Schomer and Assoc., Inc., 2117 Robert Dr., Champaign, IL 61821, schomer@SchomerAndAssociates.com) and George Hessler (Hessler Assoc., Haymarket, VA)

Worldwide, hundreds of wind farms have been built and commissioned. A sizeable fraction of these have had some complaints about wind farm noise, perhaps 10 to 50%. A smaller percentage of wind farms have engendered more widespread complaints and claims of adverse health effects, perhaps 1 to 10%. And in the limit (0 to 1%), there have been very widespread, vociferous complaints and in some cases people have abandoned their houses. Some advocates for potentially affected communities have opined that many will be made ill, while living miles from the nearest turbine, and some, who are wind power advocates, have opined that there is no possibility anyone can possibly be made ill from wind turbine acoustic emissions. In an attempt to ameliorate this frequently polarized situation, the ASA has established a public policy statement that calls for the development of a balanced research agenda to establish facts, where "balanced" means the research should resolve issues for all parties with a material interest, and all parties should have a seat at the table where the research plans are developed. This paper presents some thoughts and suggestions as to how this ASA public policy statement can be nurtured and brought to fruition.

9:45

3aNS4. Balancing the research approach on wind turbine effects through improving psychological factors that affect community response. Brigitte Schulte-Fortkamp (Inst. of Fluid Mech. and Eng. Acoust., TU Berlin, Einsteinufer 25, Berlin 101789, Germany, b.schulte-fortkamp@tu-berlin.de)

There is a substantial need to find a balanced approach to deal with people's concern about wind turbine effects. Indeed, the psychological factors that affect community response will be an important facet in this complete agenda development. Many of these relevant issues are related to the soundscape concept which was adopted as an approach to provide a more holistic evaluation of "noise" and its effects on the quality of life. Moreover, the soundscape technique uses a variety of investigation techniques, taxonomy and measurement methods. This is a necessary protocol to approach a subject or phenomenon, to improve the validity of the research or design outcome and to reduce the uncertainty of relying only on one approach. This presentation will use recent data improving the understanding about the role of psychoacoustic parameters going beyond equivalent continuous sound level in wind turbine affects in order to discuss relevant psychological factors based on soundscape techniques.

10:05–10:25 Break

Contributed Papers

10:25

3aNS5. Measurement and synthesis of wind turbine infrasound. Bruce E. Walker (Channel Islands Acoust., 676 W Highland Dr., Camarillo, CA 93010, noiseybw@aol.com) and Joseph W. Celano (Newson-Brown Acoust. LLC, Santa Monica, CA)

As part of an ongoing investigation into the putative subjective effects of sub-20 Hz acoustical emissions from large industrial wind turbines, measurement techniques for faithful capture of emissions waveforms have been developed and reported. To evaluate perception thresholds, Fourier synthesis and high fidelity low-frequency playback equipment has been used to duplicate in a residential-like listening environment the amplitudes and wave slopes of the actual emissions, with pulsation rate in the range of 0.5–1.0 per second. Further, the amplitudes and slopes of the synthesized waves can be parametrically varied and the harmonic phases "scrambled" to assess the relative effects on auditory and other subjective responses. Measurement and synthesis system details and initial subjective response results will be shown.

10:40

3aNS6. Propagation of wind turbine noise through the turbulent atmosphere. Yuan Peng, Nina Zhou, Jun Chen, and Kai Ming Li (Mech. Eng., Purdue Univ., 177 South Russel St., West Lafayette, IN 47907-2099, peng45@purdue.edu)

It is well known that turbulence can cause fluctuations in the resulting sound fields. In the issue of wind turbine noise, such effect is non-negligible since either the inflow turbulence from nearby turbine wakes or the atmospheric turbulence generated by rotating turbine blades can increase the sound output of individual turbines. In this study, a combined approach of the Finite Element Method (FEM) and Parabolic Equation (PE) method is employed to predict the sound levels from a wind turbine. In the prediction procedure, the near field acoustic data is obtained by means of a computational fluid dynamic program which serves as a good starting field of sound propagation. It is then possible to advance wind turbine noise in range by using the FEM/PE marching algorithm. By incorporating the simulated turbulence profiles near wind turbine, more accurate predictions of sound field in realistic atmospheric conditions are obtained.

10:55–12:00 Panel Discussion

WEDNESDAY MORNING, 29 OCTOBER 2014 INDIANA C/D, 8:20 A.M. TO 11:30 A.M.

Session 3aPA

Physical Acoustics, Underwater Acoustics, Structural Acoustics and Vibration, and Noise: Acoustics of Pile Driving: Models, Measurements, and Mitigation

Kevin M. Lee, Cochair
Applied Research Laboratories, The University of Texas at Austin, 10000 Burnet Road, Austin, TX 78758

Mark S. Wochner, Cochair
AdBmTechnologies, 1605 McKinley Ave., Austin, TX 78702

Invited Papers

8:20

3aPA1. Understanding effects of man-made sound on fishes and turtles: Gaps and guidelines. Arthur N. Popper (Biology, Univ. of Maryland, Biology/Psych. Bldg., College Park, MD 20742, apopper@umd.edu) and Anthony D. Hawkins (Loughine Ltd, Aberdeen, United Kingdom)

Mitigating measures may be needed to protect animals and humans that are exposed to sound from man-made sources. In this context, the levels of man-made sound that will disrupt behavior or physically harm the receiver should drive the degree of mitigation that is needed. If a particular sound does not affect an animal adversely, then there is no need for mitigation! The problem then is to know the sound levels that can affect the receiving animal. For most marine animals, there are relatively few data to develop guidelines that can help formulate the levels at which mitigation is needed. In this talk, we will review recent guidelines for fishes and turtles. Since so much remains to be determined in order to make guidelines more useful, it is important that priorities be set for future research. The most critical data, with broadest implications for marine life, should be obtained first. This paper will also consider the most critical gaps and present recommendations for future research.

8:40

3aPA2. The relationship between underwater sounds generated by pile driving and fish physiological responses. Michele B. Halvorsen (CSA Ocean Sci. Inc., 8502 SW Kanner Hwy, Stuart, FL 334997, mhalvorsen@conshelf.com)

Assessment of fish physiology after exposure to impulsive sound has been limited by quantifying physiological injuries, which range from mortal to recoverable. A complex panel of injuries was reduced to a single metric by a model called the Fish Index of Trauma. Over several years, six species of fishes from different morphological groupings, (e.g., physoclistous, physostomous, and lack of a swim bladder) were studied. The onset of physiological tissue effect was determined across a range of cumulative sound exposure levels with varying number of pile strikes. Follow up studies included investigation of healing from incurred injuries. The level of injury that animals expressed was influenced by their morphological grouping. Finally, investigation of the inner ear sensory hair cells showed that damage occurred at higher sound exposure levels than when the onset of tissue injury would occur.

9:00

3aPA3. A model to predict tissue damage in fishes from vibratory and impact pile driving. Mardi C. Hastings (George W. Woodruff School of Mech. Eng., Georgia Inst. of Technol., Atlanta, GA 30332-0405, mardi.hastings@gatech.edu)

Predicting effects of underwater pile driving on marine life requires coupling of pile source models with biological receiver models. Fishes in particular are very vulnerable to tissue damage and hearing loss from pile driving activities, especially since they are often restricted to specific habitat sites and migratory routes. Cumulative sound exposure level is the metric used by government agencies for sound exposure criteria to protect marine animals. In recent laboratory studies, physical injury and hearing loss in fish from simulated impact pile driving signals have even been correlated with this metric. Mechanisms for injury and hearing loss in fishes, however, depend on relative acoustic particle motion within the body of the animal, which can be disproportionately large in the vicinity of a pile. Modeling results will be presented showing correlation of auditory tissue damage in three species of fish with relative particle motion that can be generated 10–20 m from driving a 24-in diameter steel pile with an impact hammer. Comparative results with vibratory piling based on measured waveforms indicate that particle motion mechanisms may provide an explanation why the very large cumulative sound exposure levels associated with vibratory pile driving do not produce tissue damage.

9:20

3aPA4. Pile driving pressure and particle velocity at the seabed: Quantifying effects on crustaceans and groundfish. James H. Miller, Gopu R. Potty, and Hui-Kwan Kim (Ocean Eng., Univ. of Rhode Island, URI Bay Campus, 215 South Ferry Rd., Narragansett, RI 02882, miller@egr.uri.edu)

In the United States, offshore wind farms are being planned and construction could begin in the near future along the East Coast of the US. Some of the sites being considered are known to be habitat for crustaceans such as the American lobster, *Homarus americanus,* which has a range from New Jersey to Labrador along the coast of North America. Groundfish such as summer flounder, *Paralichthys dentatus,* and winter flounder, *Pseudopleuronectes americanus,* also are common along the East Coast of the US. Besides sharing the seafloor in locations where wind farms are planned, all three of these species are valuable commercially. We model the effects on crustaceans, groundfish, and other animals near the seafloor due to pile driving. Three different waves are investigated including the compressional wave, shear wave and interface wave. A Finite Element (FE) technique is employed in and around the pile while a Parabolic Equation (PE) code is used to predict propagation at long ranges from the pile. Pressure, particle displacement, and particle velocity are presented as a function of range at the seafloor for a shallow water environment near Rhode Island. We will discuss the potential effects on animals near the seafloor.

9:40

3aPA5. Finite difference computational modeling of marine impact pile driving. Alexander O. MacGillivray (JASCO Appl. Sci., 2305–4464 Markham St., Victoria, BC V8Z7X8, Canada, alex@jasco.com)

Computational models based on the finite difference (FD) method can be successfully used to predict underwater pressure waves generated by marine impact pile driving. FD-based models typically discretize the equations of motion for a cylindrical shell to model the vibrations of a submerged pile in the time-domain. However, because the dynamics of a driven pile are complex, realistic models must also incorporate physics of the driving hammer and surrounding acousto-elastic media into the FD formulation. This paper discusses several of the different physical phenomena involved, and shows some approaches to simulating them using the FD method. Topics include dynamics of the hammer and its coupling to the pile head, transmission of axial pile vibrations into the soil, energy dissipation at the pile wall due to friction, acousto-elastic coupling to the surrounding media, and near-field versus far-field propagation modeling. Furthermore, this paper considers the physical parameters required for predictive modeling of pile driving noise in conjunction with some practical considerations about how to determine these parameters for real-world scenarios.

10:00–10:20 Break

10:20

3aPA6. On the challenges of validating a profound pile driving noise model. Marcel Ruhnau, Tristan Lippert, Kristof Heitmann, Stephan Lippert, and Otto von Estorff (Inst. of Modelling and Computation, Hamburg Univ. of Technol., Denickestraße 17, Hamburg, Hamburg 21073, Germany, mub@tuhh.de)

When predicting underwater sound levels for offshore pile driving by using numerical simulation models, appropriate model validation becomes of major importance. In fact, different parallel transmission paths for sound emission into the water column, i.e., pile-to-water, pile-to-soil, and soil-to-water, make a validation at each of the involved interfaces necessary. As the offshore environment comes with difficult and often unpredictable conditions, measurement campaigns are very time consuming and cost intensive. Model developers have to keep in mind that even thorough planning cannot overcome practical restrictions as well as technical limits and thus require for a reasonable model balancing. The current work presents the validation approach chosen for a comprehensive pile driving noise model—consisting of a near field finite element model as well as a far field propagation model—that is used for the prediction of noise levels at offshore wind farms.

10:40

3aPA7. Underwater noise and transmission loss from vibratory pile driving. Peter H. Dahl and Dara M. Farrell (Appl. Phys. Lab. and Mech. Eng. Dept., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, dahl@apl.washington.edu)

High levels of underwater sound can be produced in vibratory pile driving that can carry regulatory implications. In this presentation, observations of underwater noise from vibratory pile driving made with a vertical line array placed at range 17 m from the source (water depth 7.5 m) are discussed, along with simultaneous measurements made at ranges of order 100 m. It is shown that the dominant spectral

features are related to the frequency of the vibratory pile driving hammer (typically 15–35 Hz), producing spectral lines at intervals of this frequency. Homomorphic analysis removes these lines to reveal the underlying variance spectrum. The mean square pressure versus depth is subsequently studied in octave bands in view of the aforementioned spectral line property, with depth variation well modeled by an incoherent sum of sources distributed over the water column. Adiabatic mode theory is used to model the range dependent local bathymetry, including the effect of elastic seabed, and comparisons are made with simultaneous measurements of the mean-square acoustic pressure at ranges 200 and 400 m. This approach makes clear headway into the problem of predicting transmission loss versus range for this method of pile driving.

Contributed Papers

11:00

3aPA8. Using arrays of air-filled resonators to attenuate low frequency underwater sound. Kevin M. Lee, Andrew R. McNeese (Appl. Res. Labs., The Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758, klee@arlut.utexas.edu), Preston S. Wilson (Mech. Eng. Dept. and Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX), and Mark S. Wochner (AdBm Technologies, Austin, TX)

This paper investigates the acoustic behavior of underwater air-filled resonators that could potentially be used in an underwater noise abatement system. The resonators are similar to Helmholtz resonators without a neck, consisting of underwater inverted air-filled cavities with combinations of rigid and elastic wall members, and they are intended to be fastened to a framework to form a stationary array surrounding a noise source, such as a marine pile driving operation, a natural resource production platform, or an air gun array, or to protect a receiving area from outside noise. Previous work has demonstrated the potential of surrounding low frequency sound sources with arrays of large stationary encapsulated bubbles that can be designed to attenuate sound levels over any desired frequency band and with levels of reduction up to 50 dB [Lee and Wilson, Proceedings of Meeting on Acoustics **19**, 075048 (2013)]. Open water measurements of underwater sound attenuation using resonators were obtained during a set of lake experiments, where a low-frequency electromechanical sound source was surrounded by different arrays of resonators. The results indicate that air-filled resonators are a potential alternative to using encapsulated bubbles for low frequency underwater noise mitigation. [Work supported by AdBm Technologies.]

11:15

3aPA9. Axial impact driven buckling dynamics of slender beams. Josh R. Gladden (Phys. & NCPA, Univ. of MS, 108 Lewis Hall, University, MS 38677, jgladden@olemiss.edu), Nestor Handzy, Andrew Belmonte (Dept. of Mathematics, The Penn State Univ., University Park, PA), and E. Villermaux (Institut de Recherche sur les Phenomenes Hors Equilibre, Universite de Provence, Marseille, France)

We present experiments on the dynamic buckling of slender rods axially impacted by a projectile. By combining the results of Saint-Venant and elastic beam theory, we derive a preferred wavelength for the buckling instability, and experimentally verify the resulting scaling law for a range of materials using high speed video analysis. The scaling law for the preferred excitation mode depends on the ratio of the longitudinal speed of sound in the beam to the impact speed of the projectile. We will briefly present the imprint of this deterministic mechanism on the fragmentation statistics for brittle beams.

WEDNESDAY MORNING, 29 OCTOBER 2014 MARRIOTT 1/2, 8:00 A.M. TO 9:20 A.M.

Session 3aSAa

Structural Acoustics and Vibration, Architectural Acoustics, and Noise: Vibration Reduction in Air-Handling Systems

Benjamin M. Shafer, Chair
Technical Services, PABCO Gypsum, 3905 N 10th St, Tacoma, WA 98406

Chair's Introduction—8:00

Invited Papers

8:05

3aSAa1. Vibration reduction in air handling systems. Angelo J. Campanella (Acculab, Campanella Assoc., 3201 Ridgewood Dr., Ohio, Hilliard, OH 43026, a.campanella@att.net)

Air handling units (AHU) mounted on elevated floors in old and new buildings can create floor vibrations that transmit through the building structure to perturb nearby occupants and sensitive equipment such as electron microscopes. Vibration sources include rotating fan imbalance and air turbulence. Isolation springs and the deflecting floor then create a two degree of freedom system. The analysis discussed here was originally published in "Sound and Vibration," October 1987, pp. 26–30. Analysis parameters will be discussed along with inertia block affects and spring design strategy for floors of finite mass.

8:25

3aSAa2. Determining fan generated dynamic forces for use in predicting and controlling vibration and structure-borne noise from air handling equipment. James E. Phillips (Wilson, Ihrig & Assoc., Inc., 6001 Shellmound St., Ste. 400, Emeryville, CA 94608, jphillips@wiai.com)

Vibration measurements were conducted to determine the dynamic forces imparted by an operating fan to the floor of an existing rooftop mechanical room. The calculated forces where then used as inputs to a Finite Element Analysis (FEA) computer model to predict the vibration and structure-borne noise in a future building with a similar fan. This paper summarizes the vibration measurements, analysis of the measured data, the subsequent FEA analysis of the future building and the recommendations developed to control fan generated noise and vibration in the future building.

8:45

3aSAa3. Vibration isolation of mechanical equipment: Case studies from light weight offices to casinos. Steve Pettyjohn (The Acoust. & Vib. Group, Inc., 5765 9th Ave., Sacramento, CA CA, spettyjohn@acousticsandvibration.com)

Whether to vibration isolate HVAC equipment or not is often left to the discretion of the mechanical engineer or the equipment supplier. Leaving he isolators out saves money in materials and installation. The value of putting them is not so clear. The cost of not installing the isolators is seldom understood nor the cost of installing them later and the loss of trust by the client. Vibration is generated by all rotating and reciprocating equipment. The resulting unbalanced forces ares seldom known with certainty nor are they quantified. This paper explores the isolation of HVAC equipment on roof, penthouses and roofs without consideration for the stiffness of the structures or resonances of other building elements. The influence of horizontal forces and the installation of the equipment to account for these forces is seldom considered. The application of restraining forces must consider where the force is applied and what the moment arm is. A quick review of the basic formulas will be given one-degree and multi-degree systems. Examples of problems that arose when the vibration isolated was not considered will be presented for a variety of conditions. The corrective actions will be given also.

Contributed Paper

9:05

3aSAa4. Transition of steady air flow into an anharmonic acoustic pulsed flow in a prototype reactor column: Experimental results and mathematical modeling. Hasson M. Tavossi (Phys., Astronomy, & Geo-Sci., Valdosta State University, 2402 Spring Valley Cir, Valdosta, GA 31602, htavossi@valdosa.edu)

A prototype experimental setup is designed to convert steady air flow into an oscillatory anharmonic acoustic pulsed flow, under special experimental conditions. The steady flow in a cylindrical reactor column of 3 m height and 15 cm in diameter with a porous layer, transforms itself abruptly into an oscillatory acoustic pulsed flow. Experimental results show the existence of a threshold for flow-rate, beyond which this transformation into anharmonic oscillatory flow takes place. This change in flow regime is analogous to the phenomenon of bifurcation in a chaotic system, with abrupt change from one energy state into another. Experimental results show that the acoustic oscillations amplitude depends on system size. Preliminary mathematical model will be presented that includes; relaxation oscillations, non-equilibrium thermodynamics, and Joule-Thomson effect. The frequencies at peak amplitude for the acoustic vibrations in the reactor column are expressed in terms of flow-rate, pressure-drop, viscosity, and dimensionless characteristic numbers of the air flow in the system.

WEDNESDAY MORNING, 29 OCTOBER 2014 MARRIOTT 1/2, 10:00 A.M. TO 12:00 NOON

Session 3aSAb

Structural Acoustics and Vibration: General Topics in Structural Acoustics and Vibration

Benjamin Shafer, Chair
Technical Services, PABCO Gypsum, 3905 N 10th St., Tacoma, WA 98406

Contributed Papers

10:00

3aSAb1. Design of an experiment to measure unsteady shear stress and wall pressure transmitted through an elastomer in a turbulent boundary layer. Cory J. Smith (Appl. Res. Lab., The Penn State Univ., 1109 Houserville Rd., State College, PA 16801, coryjonsmith@gmail.com), Dean E. Capone, and Timothy A. Brungart (Graduate Program in Acoust., Appl. Res. Lab., The Penn State Univ., State College, PA)

A flat plate that is exposed to a turbulent boundary layer (TBL) experiences unsteady velocity fluctuations which result in fluctuating wall pressures and shear stresses on the surface of the plate. There is an interest in understanding how fluctuating shear stresses and normal pressures generated on the surface of an elastomer layer exposed to a TBL in water are transmitted through the layer onto a rigid backing plate. Analytic models exist which predict these shear stress and normal pressure spectra on the surface of the elastomer as well as those transmitted through the elastomer. The design of a novel experiment is proposed which will utilize Surface Stress Sensitive Films (S3F) to measure the fluctuating shear stress and hydrophones to measure fluctuating normal pressure at the elastomer-plate interface. These experimental measurements would then be compared to

models of unsteady shear and unsteady pressure spectra within a TBL for purposes of model validation. This work will present the design of an experiment to measure the unsteady pressure and unsteady shear at the elastomer-plate interface and the methodology for comparing the measured results to the analytic model predictions.

10:15

3aSAb2. Exploration into the sources of error in the two-microphone transfer function impedance tube method. Hubert S. Hall (Naval Surface Warfare Ctr. Carderock Div., 9500 MacArthur Blvd., West Bethesda, MD 20817, hubert.hall@navy.mil), Joseph Vignola, John Judge (Dept. of Mech. Eng., The Catholic Univ. of America, Washington, DC), and Diego Turo (Dept. of Biomedical Eng., George Mason Univ., Fairfax, VA)

The two-microphone transfer function method has become the most widely used method of impedance tube testing. Due to its measurement speed and ease of implementation, it has surpassed the standing-wave ratio method in popularity despite inherent frequency limitations due to tube geometry. Currently, the two-microphone technique is described in test standards ASTM E1050 and ISO 10534-2 to ensure accurate measurement. However, while detailed for correct test execution, the standards contain vague recommendations for a variety of measurement parameters. For instance, it is only stated in ASTM E1050 that "tube construction shall be massive so sound transmission through the tube wall is negligible." To quantify this requirement, damping of the tube was varied to determine how different loss factor values effect measured absorption coefficient values. Additional sources of error explored are the amount of required absorbing material within the tube for reflective material measurements, additional calibration methods needed for test of excessive reflective materials, and alternate methods of combating microphone phase error and tube attenuation.

10:30

3aSAb3. Analysis of the forced response and radiation of a single-dimpled beam with different boundary conditions. Kyle R. Myers and Koorosh Naghshineh (Mech. & Aerosp. Eng., Western Michigan Univ., College of Eng. & Appl. Sci., 4601 Campus Dr., Kalamazoo, MI 49008, kyle.r.myers@wmich.edu)

Beading and dimpling via the stamping process has been used for decades to stiffen structures (e.g., beams, plates, and shells) against static loads and buckling. Recently, this structural modification technique has been used as a means to shift a structure's natural frequencies and to reduce its radiated sound power. Most studies to date have modeled dimpled beams and dimpled/beaded plates using the finite element method. In this research, an analytical model is developed for a beam with any number of dimples using Hamilton's Principle. First, the natural frequencies and mode shapes are predicted for a dimpled beam in free transverse vibration. A comparison with those obtained using the finite element method shows excellent agreement. Second, the forced response of a dimpled beam is calculated for a given input force. Mode shapes properly scaled from the forced response are used in order to calculate the beam strain energy, thus demonstrating the effect of dimpling on beam natural frequencies. Finally, some preliminary results are presented on the changes in the radiation properties of dimpled beams.

10:45

3aSAb4. The impact of CrossFit training—Weight drops on floating floors. Richard S. Sherren (Kinetics Noise Control, 6300 Irelan Pl., Dublin, OH 43062, rsherren@kineticsnoise.com)

CrossFit training is a popular fitness training method. Some facilities install lightweight plywood floating floor systems as a quick, inexpensive method to mitigate impact generated noise and vibration into adjoining spaces. Part of the CrossFit training regimen involves lifting significant weight overhead, and then dropping the weight on the floor. The energy transferred to the floor system can cause severe damage to floor surfaces and structures; and, when using a lightweight floating floor system, even the isolators can be damaged. This paper describes a spreadsheet based analytical model being used to study the effects of such impacts on various floor systems. This study is a prelude to experiments that will be performed on a full scale model test floor. The results of those experiments will be used to verify the model so that it can be used as a design tool for recommending solutions for mitigating the noise and vibration in adjoining spaces due to floor impact problems. Also discussed in this paper are the qualitative results of some preliminary tests performed in order to better understand the mechanics of impacts on floating floor assemblies.

11:00

3aSAb5. Stethoscope-based detection of detorqued bolts using impact-induced acoustic emissions. Joe Guarino (Mech. and Biomedical Eng., Boise State Univ., Boise, ID) and Robert Hamilton (civil Eng., Boise State Univ., 1910 University Dr., Boise, ID 83725, rhamilton@boisestate.edu)

Non-invasive impact analysis can be used to detect loosened bolts in a steel structure composed of construction-grade I beams. An electronically enhanced stethoscope was used to acquire signals from a moderate to light impact of a hammer on a horizontal steel I beam. Signals were recorded by placing the diaphragm of the stethoscope on the flange of either the horizontal beam or the vertical column proximal to a bolted connection connecting the two members. Data were taken using a simple open-loop method; the input signal was not recorded, nor was it used to reference the output signal. The bolted connection had eight bolts arranged in a standard configuration. Using the "turn of the nut" standard outlined by the Research Council on Structural Connections (RCSC, TDS-012 2-18-08), the bolted joint was tested in three conditions: turn of the nut tight, finger tight, and loose. We acquired time-based data from each of 52 patterns of the eight bolts in three conditions of tightness. Results of both time and frequency-based analyses show that open-loop responses associated with detorqued bolts vary in both amplitude decay and frequency content. We conclude that a basic mechanism can be developed to assess the structural health of bolted joints. Results from this project will provide a framework for further research, including the analysis of welded joints using the same approach.

11:15

3aSAb6. Creep behavior of composite interlayer and its influence on impact sound of floating floor. Tongjun Cho, Byung Kwan Oh, Yousok Kim, and Hyo Seon Park (Architectural Eng., Yonsei Univ., Yonseino 50 Seodaemun-gu, Seoul 120749, South Korea, tjcho@yonsei.ac.kr)

Creep-induced changes in dynamic stiffness of resilient interlayer used for floating floor is an important parameter of vibration isolator in long-term use. Compressive creep behavior of a composite layer made from closed-cell foam and fibrous material is investigated using a Findley equation-based method recommended by International Organization for Standardization (ISO). Quasi-static mechanical analysis is used to evaluate the dynamic stiffness influenced by the creep-deformation of the composite layer. It is shown in the present work that the long-term creep strain of the interlayer under nominal load of the floor and furniture is within the zone where dynamic stiffness increases. The changes in low frequency impact sound by the long-term creep deformation are estimated through real scale laboratory experiments and numerical vibro-acoustic analysis.

11:30

3aSAb7. Investigation of damping in the polymer concrete sleeper for use in reduction of rolling noise from railway. SangKeun Ahn, Eunbeom Jeon, Junhong Park, Hak-sung Kim (Mech. Eng., Hanyang Univ., 222, Wangsimni-ro, Seongdong-gu, Appendix of Eng. Ctr., 211, Seoul 133-791, South Korea, ask9156@hanyang.ac.kr), and Hyo-in Kho (Korea RailRd. Res. Inst., Uiwang, South Korea)

The purpose of this study was to measure damping of various polymer concretes to be used as sleepers for railway. The polymer concretes consisted of epoxy monomer, hardener and aggregates. Various polymer concrete specimens were made by changing epoxy resin weight ratio and curing temperature. The dynamic properties of the polymer concrete specimens were measured by using beam-transfer function method. To predict reduction performance of the polymer concrete sleepers, an infinite Timoshenko beam model was investigated after applying measured concrete properties. The moving loads from rotating wheels on railway due to different roughness were utilized in railway vibration analysis. The vibration response was predicted from which the effects of supporting stiffness and loss factor of sleeper were investigated. The radiated sound power was predicted using calculated rail vibration response. Consequently, the sound power levels

were compared for rails supported by different polymer concrete sleepers. The result of this study assists constructing low noise railway.

11:45

3aSAb8. Study on impulsive noise radiation from of gasoline direct injector. Yunsang Kwak and Junhong Park (Mech. Eng., Hanyang Univ., 515 FTC Hanyang Univ. 222, Wangsimni-ro Seongdong-gu, Seoul ASI|KR|KS013|Seoul, South Korea, toy0511@hanmail.net)

A gasoline direct injection (GDI) engine uses its own injectors for high pressure fuel supply to the combustion chamber. High frequency impact sound during the injection process is one of the main contributors to engine combustion noise. This impact noise is generated during opening and closing by an injector rod operated by a solenoid. For design of an injector with reduced noise generation, it is necessary to analyze its sound radiation mechanism and propose consequent evaluation method. Spectral and modal characteristics of the injectors were measured through vibration induced by external hammer excitation. The injector modal characteristics were analyzed using a simple beam after analyzing its boundaries by complex transverse and rotational springs. To evaluate impulsive sounds more effectively, Prony analysis of sounds was used for verifying influence of injector modal characteristics.

WEDNESDAY MORNING, 29 OCTOBER 2014 — MARRIOTT 5, 8:00 A.M. TO 12:00 NOON

Session 3aSC

Speech Communication: Vowels = Space + Time, and Beyond: A Session in Honor of Diane Kewley-Port

Catherine L. Rogers, Cochair
Dept. of Communication Sciences and Disorders, University of South Florida, USF, 4202 E. Fowler Ave., PCD1017, Tampa, FL 33620

Amy T. Neel, Cochair
Dept. of Speech and Hearing Sci., Univ. of New Mexico, MSC01 1195, University of New Mexico, Albuquerque, NM 87131

Chair's Introduction—8:00

Invited Papers

8:05

3aSC1. Vowels and intelligibility in dysarthric speech. Amy T. Neel (Speech and Hearing Sci., Univ. of New Mexico, MSC01 1195, University of New Mexico, Albuquerque, NM 87131, atneel@unm.edu)

Diane Kewley-Port's work in vowel perception under challenging listening conditions and in the relation between vowel perception and production in second language learners has important implications for disordered speech. Vowel space area has been widely used as an index of articulatory working space in speakers with hypokinetic dysarthria related to Parkinson disease (PD), with the assumption that a larger vowel space is associated with higher speech intelligibility. Although many studies have reported acoustic measures of vowels in Parkinson disease, vowel identification and transcription tasks designed to relate changes in production with changes in perception are rarely performed. This study explores the effect of changes in vowel production by six talkers with PD speaking at habitual and loud levels of effort on listener perception. The relation among vowel acoustic measures (including vowel space area and measures of temporal and spectral distinctiveness), vowel identification scores, speech intelligibility ratings, and sentence transcription accuracy for speakers with dysarthria will be discussed.

8:25

3aSC2. Vowels in clear and conversational speech: Within-talker variability in acoustic characteristics. Sarah H. Ferguson and Lydia R. Rogers (Commun. Sci. and Disord., Univ. of Utah, 390 South 1530 East, Rm. 1201, Salt Lake City, UT 84112, sarah.ferguson@hsc.utah.edu)

The Ferguson Clear Speech Database was developed for the first author's doctoral dissertation, which was directed by Diane Kewley-Port at Indiana University. While most studies using the Ferguson Database have examined variability among the 41 talkers, the present investigation considered within-talker differences. Specifically, this study examined the amount of variability each talker showed among the 7 tokens of each of 10 vowels produced in clear versus conversational speech. Steady-state formant frequencies have been measured for 5740 vowels in /bVd/ context using PRAAT, and a variety of measures of spread will be used to determine variability for each vowel in each speaking style for each talker. Results will be compared to those of the only known previous study that included a sufficiently large number of tokens for this type of analysis, an unpublished thesis from 1980. Based on this study, we predict that within-token variability will be smaller in clear speech than in conversational speech.

8:45

3aSC3. Understanding speech from partial information: The contributions of consonants and vowels. Daniel Fogerty (Commun. Sci. and Disord., Univ. of South Carolina, 1621 Greene St., Columbia, SC 29208, fogerty@sc.edu)

In natural listening environments, speech is commonly interrupted by background noise. These environments require the listener to extract meaningful speech cues from the partially preserved acoustic signal. A number of studies have now investigated the relative contribution of preserved consonant and vowel segments to speech intelligibility using an interrupted speech paradigm that selectively preserves these segments. Results have demonstrated that preservation of vowel segments results in greater intelligibility for sentences compared to consonant segments, especially after controlling for preserved duration. This important contribution from vowels is specific to sentence contexts and appears to result from suprasegmental acoustic cues. Converging evidence from acoustic and behavioral investigations suggests that these cues are primarily conveyed through temporal amplitude modulation of vocalic energy. Additional empirical evidence suggests that these temporal cues of vowels, conveying the rhythm and stress of speech, are important for interpreting global linguistic cues about the sentence, such as involved in syntactic processing. In contrast, consonant contributions appear to be specific to lexical access regardless of the linguistic context. Work testing older adults with normal and impaired hearing demonstrates their preserved sensitivity to contextual cues conveyed by vowels, but not consonants. [Work supported by NIH.]

9:05

3aSC4. Vowel intelligibility and the second-language learner. Catherine L. Rogers (Dept. of Commun. Sci. and Disord., Univ. of South Florida, USF, 4202 E. Fowler Ave., PCD1017, Tampa, FL 33620, crogers2@usf.edu)

Diane Kewley-Port's work has contributed to our understanding of vowel perception and production in a wide variety of ways, from mapping the discriminability of vowel formants in conditions of minimal uncertainty to vowel processing in challenging conditions, such as increased presentation rate and noise. From the results of these studies, we have learned much about the limits of vowel perception for normal-hearing listeners and the robustness of vowels in speech perception. Continuously intertwined with this basic research has been its application to our understanding of vowel perception and vowel acoustics across various challenges, such as hearing impairment and second-language learning. Diane's work on vowel perception and production by second-language learners and ongoing research stemming from her influence will be considered in light of several factors affecting communicative success and challenge for second-language learners. In particular, we will compare the influence of speaking style, noise, and syllable disruption on the intelligibility of vowels perceived and produced by native and non-native English-speaking listeners.

9:25

3aSC5. Vowel formant discrimination: Effects of listeners' hearing status and language background. Chang Liu (Commun. Sci. and Disord., The Univ. of Texas at Austin, 1 University Station A1100, Austin, TX 78712, changliu@utexas.edu)

The goal of this study was to examine effects of listeners' hearing status (e.g., normal and impaired hearing) and language background (e.g., native and non-native) on vowel formant discrimination. Thresholds of formant discrimination were measured for F1 and F2 of English vowels at 70 dB SPL for normal- (NH) and impaired-hearing (HI) listeners using a three-interval, two-alternative forced-choice procedure with a two-down, one-up tracking algorithm. Formant thresholds of HI listeners were comparable to those of NH listeners for F1, but significantly higher than NH listeners for F2. Results of a further experiment indicated that an amplification of the F2 peak could markedly improve formant discrimination for HI listeners, but a simple amplification of the sound level did not provide any benefit to them. On the other hand, another experiment showed that vowel density of listeners' native language appeared to affect vowel formant discrimination, i.e., more crowded vowel space of listeners' native language, better their vowel formant discrimination. For example, English-native listeners showed significantly lower thresholds of formant discrimination for both English and Chinese vowels than Chinese-native listeners. However, the two groups of listeners had similar psychophysical capacity to discriminate formant frequency changes in non-speech sounds.

9:45

3aSC6. Consonant recognition in noise for bilingual children with simulated hearing loss. Kanae Nishi, Andrea C. Trevino (Boys Town National Res. Hospital, 555 N. 30th St., Omaha, NE 68131, kanae.nishi@boystown.org), Lydia Rosado Rogers (Commun. Sci. and Disord., Univ. of Utah, Omaha, Nebraska), Paula B. Garcia, and Stephen T. Neely (Boys Town National Res. Hospital, Omaha, NE)

The negative impacts of noisy listening environments and hearing loss on speech communication are known to be greater for children and non-native speakers than adult native speakers. Naturally, the synergistic influence of listening environment and hearing loss is expected to be greater for bilingual children than their monolingual or normal-hearing peers, but limited studies have explored this issue. The present study compared the consonant recognition performance of highly fluent school-age Spanish-English bilingual children to that of monolingual English-speaking peers. Stimulus materials were 13 English consonants embedded in three symmetrical vowel-consonant-vowel (VCV) syllables. To control for variability in hearing loss profiles, mild-to-moderate sloping sensorineural hearing loss modeled after Pittman & Stelmachowicz [Ear Hear 24, 198–205 (2003)] was simulated following the method used by Desloge *et al.* [Trends Amplification 16(1), 19–39 (2012)]. Listeners heard VCVs in quiet and in the background of speech-shaped noise with and without simulated hearing loss. Overall performance and the recognition of individual consonants will be discussed in terms of the influence of language background (bilingual vs. monolingual), listening condition, simulated hearing loss, and vowel context. [Work supported by NIH.].

10:05–10:20 Break

10:20

3aSC7. Distributions of confusions for the 109 syllable constituents that make up the majority of spoken English. James D. Miller, Charles S. Watson, and Roy Sillings (Res., Commun. Disord. Technol., Inc., 3100 John Hinkle Pl, Ste. 107, Bloomington, IN 47408, jamdmill@indiana.edu)

Among the interests of Kewley-Port have been the perception and production of English Speech Sounds by native speakers of other languages. ESL students from four language backgrounds (Arabic, Chinese, Korean, and Spanish) were enrolled in a speech perception training program. Similarities and differences between these L1 groups in their primary confusions were determined for onsets, nuclei and codas utilized in spoken English. An analysis in terms of syllable constituents is more meaningful than analyses in terms of phonemes as individual phonemes have differing articulatory and acoustic structures depending on their roles in the syllable and their phonetic environments. An important observation is that only a few of all the possible confusions that might occur do occur. Another interesting characteristic of confusions among syllable constituents is that many more confusions are observed than those popularly cited, e.g., the /r/ v /l/ for Japanese speakers. As noted by many, the perceptual problems encountered by learners of English are conditioned on the relations between the sound-structures of English with each talker's L1. These data suggest that the intrinsic similarities within of the sounds of English also play an important role.

10:40

3aSC8. Identification and response latencies for Mandarin-accented isolated words in quiet and in noise. Jonathan Dalby (Commun. Sci. and Disord., Indiana-Purdue, Fort Wayne, 2101 East Coliseum Blvd., Fort Wayne, IN 46805, dalbyj@ipfw.edu), Teresa Barcenas (Speech and Hearing Sci., Portland State Univ., Portland, OR), and Tanya August (Speech-Lang. Pathol., G-K-B Community School District, Garrett, IN)

This study compared the intelligibility of native and foreign-accented American English speech presented in quiet and mixed with two different levels of background noise. Two native American English speakers and two native Mandarin Chinese speakers for whom English is a second language read three 50-word lists of phonetically balanced words (Stuart, 2004). The words were mixed with noise at three different signal-to-noise levels—no noise (quiet), SNR + 10 dB (signal 10 dB louder than noise) and SNR 0 (signal and noise at equal loudness). These stimuli were presented to ten native American English listeners who were simply asked to repeat the words they heard the speakers say. Listener response latencies were measured. The results showed that for both native and accented speech, response latencies increased as the noise level increased. For words identified correctly, response times to accented speech were longer than for native speech but the noise conditions affected both types equally. For words judged incorrectly, however, the noise conditions increased latencies for accented speech more than for native speech. Overall, these results support the notion that processing accented speech requires more cognitive effort than processing native speech.

11:00

3aSC9. The contribution of vowels to auditory-visual speech recognition and the contributions of Diane Kewley-Port to the field of speech communication. Carolyn Richie (Commun. Sci. & Disord., Butler Univ., 4600 Sunset Ave, Indianapolis, IN 46208, crichie@butler.edu)

Throughout her career, Diane Kewley-Port has made enduring contributions to the field of Speech Communication in two ways—through her research on vowels and through her mentoring. Diane has contributed greatly to current knowledge about vowel acoustics, vowel discrimination and identification, and the role of vowels in speech recognition. Within that line of research, Richie & Kewley-Port (2008) investigated the effects of visual cues to vowels on speech recognition. Specifically, we demonstrated that an auditory-visual vowel-identification training program benefited sentence recognition under difficult listening conditions more than consonant-identification training and no training. In this presentation, I will describe my continuing research on the relationship between auditory-visual vowel-identification training and listening effort, for adults with normal hearing. In this study, listening effort was measured in terms of response time and participants were tested on auditory-visual sentence recognition in noise. I will discuss the ways that my current work has been inspired by past research with Diane, and how her mentoring legacy lives on.

11:20

3aSC10. Individual differences in the perception of nonnative speech. Tessa Bent (Dept. of Speech and Hearing Sci., Indiana Univ., 200 S. Jordan Ave., Bloomington, IN 47405, tbent@indiana.edu)

As a mentor, Diane Kewley-Port was attentive to each student's needs and took a highly hands-on, individualized approach. In many of her collaborative research endeavors, she has also taken a fine-grained approach toward both discovering individual differences in speech perception and production as well as explaining the causes and consequences of this range of variation. I will present research investigating several cognitive-linguistic factors that may contribute to individual differences in the perception of nonnative speech. Recognizing words from nonnative talkers can be particularly difficult when combined with environmental degradation (e.g., background noise) or listener limitations (e.g., child listener). Under these conditions, the range of performance across listeners is substantially wider than observed under more optimal conditions. My work has investigated these issues in monolingual and bilingual adults and children. Results have indicated that age, receptive vocabulary, and phonological awareness are predictive of nonnative word recognition. Factors supporting native word recognition, such as phonological memory, were less strongly associated with nonnative word recognition. Together, these results suggest that the ability to accurately perceive nonnative speech may rely, at least partially, on different underlying cognitive-linguistic abilities than those recruited for native word recognition. [Work supported by NIH-R21DC010027.]

11:40

3aSC11. Individual differences in sensory and cognitive processing across the adult lifespan. Larry E. Humes (Indiana Univ., Dept. Speech & Hearing Sci., Bloomington, IN 47405-7002, humes@indiana.edu)

A recent large-scale (N = 245) cross-sectional study of threshold sensitivity and temporal processing in hearing, vision and touch for adults ranging in age from 18 through 82 years of age questioned the long-presumed link between aging and declines in cognitive-processing [Humes, L.E., Busey, T.A., Craig, J. & Kewley-Port, D. (2013). Attention, Perception and Psychophysics, 75, 508–524]. The results of this extensive psychophysical investigation suggested that individual differences in sensory processing across multiple tasks and senses drive individual differences in cognitive processing in adults regardless of age. My long-time colleague at IU, Diane Kewley-Port, was instrumental in the design, execution and interpretation of results for this large study, especially for the measures of auditory temporal processing. The methods used and the results obtained in this study will be reviewed, with a special emphasis on the auditory stimuli and tasks involved. The potential implications of these findings, including possible interventions, will also be discussed. Finally, future research designed to better evaluate the direction of the association between sensory-processing and cognitive-processing deficits will be described. [Work supported, in part, by research grant R01 AG008293 from the NIA.]

WEDNESDAY MORNING, 29 OCTOBER 2014 — INDIANA G, 8:30 A.M. TO 10:00 A.M.

Session 3aSPa

Signal Processing in Acoustics: Beamforming and Source Tracking

R. Lee Culver, Chair
ARL, Penn State University, PO Box 30, State College, PA 16804

Contributed Papers

8:30

3aSPa1. An intuitive look at the unscented Kalman filter. Edmund Sullivan (Res., prometheus, 46 Lawton Brook Ln., Portsmouth, RI 02871, bewegungslos@fastmail.fm)

The Unscented Kalman Filter or UKF is a powerful and easily used modification to the Kalman filter that permits it use in the case of a nonlinear process or measurement model. Its power lies in its ability to allow the mean and covariance of the data to be correctly passed through a nonlinearity, regardless of the form of the nonlinearity. There is a great deal of literature on the UKF that describes the method and gives instruction on its use, but there are no clear descriptions on why it works. In this paper, we show that by computing the mean and covariance as the expectations of a Gaussian process, passing the results through a nonlinearity and solving the resulting integrals using Gauss-Hermite quadrature, the reason for the ability of the UKF to maintain the correct mean and covariance is explained by the fact that the Gauss-Hermite quadrature uses the same abscissas and weights regardless of the form of the integrand.

8:45

3aSPa2. Tracking unmanned aerial vehicles using a tetrahedral microphone array. Geoffrey H. Goldman (U.S. Army Res. Lab., 2800 Powder Mill Rd., Adelphi, MD 20783-1197, geoffrey.h.goldman.civ@mail.mil) and R. L. Culver (Appl. Res. Lab., Penn State Univ., State College, PA)

Unmanned Aerial Vehicles (UAVs) present a difficult localization problem for traditional radar systems due to their small radar cross section and relatively slow speeds. To help address this problem, the U.S. Army Research Laboratory (ARL) is developing and testing acoustic-based detection and tracking algorithms for UAVs. The focus has been on detection, bearing and elevation angle estimation using either minimum mean square error or adaptive beamforming methods. A model-based method has been implemented which includes multipath returns, and a Kalman filter has been implemented for tracking. The acoustic data were acquired using ARL's tetrahedral microphone array against several UAV's. While the detection and tracking algorithms perform reasonably well, several challenges remain. For example, interference from other sources resulted in lower signal to interference ratio (SIR), which can significantly degrade performance. The presence of multipath nearly always results in greater variance in elevation angle estimates than in bearing angle estimates.

9:00

3aSPa3. An ultrasonic echo characterization approach based on particle swarm optimization. Adam Pedrycz (Sonic/LWD, Schlumberger, 2-2-1 Fuchinobe, Sagamihara, Kanagawa 229-0006, Japan, APedrycz@slb.com), Henri-Pierre Valero, Hiroshi Hori, Kojiro Nishimiya, Hitoshi Sugiyama, and Yoshino Sakata (Sonic/LWD, Schlumberger, Sagamihara, Kanagawa-ken, Japan)

Presented is a hands-free approach for the extraction and characterization of ultrasonic echoes embedded in noise. By means of model-based nondestructive evaluation approaches, echoes can be represented parametrically by arrival time, amplitude, frequency, etc. Inverting for such parameters is a non-linear task, usually employing gradient-based, least-squared minimization such as Gauss-Newton (GN). To improve inversion stability, suitable initial echo parameter guesses are required which may not be possible under the presence of noise. To mitigate this requirement, particle swarm optimization (PSO) is employed in lieu of GN. PSO is a population-based optimization technique wherein a swarm of particles explores a multidimensional search space of candidate solutions. Particles seek out the global optimum by iteratively moving to improve their position by evaluating their individual performance as well as that of the collective. Since the inversion problem is non-linear, multiple suboptimal solutions exist, and in this regard PSO has a much lower propensity of becoming trapped in a local minima compared to gradient-based approaches. Due to this, it is possible to omit initial guesses and utilize a broad search range instead, which becomes far more trivial. Real pulse-echoes were used to evaluate the efficacy of the PSO approach under varying noise severity. In all cases, PSO characterized the echo correctly while GN required an initial guess within 30% of the true value to converge.

9:15

3aSPa4. Beamspace compressive spatial spectrum estimation on large aperture acoustic arrays. Geoffrey F. Edelmann, Jeffrey S. Rogers, and Steve L. Means (Acoust., Code 7160, U. S. Naval Res. Lab., 4555 Overlook Ave SW, Code 7162, Washington, DC 20375, edelmann@nrl.navy.mil)

For large aperture sonar arrays, the number of acoustic elements can be quite sizable and thus increase the dimensionality of the l1 minimization required for compressive beamforming. This leads to high computational complexity that scales by the cube of the number of array elements. Furthermore, in many applications, raw sensor outputs are often not available since computation of the beamformer power is a common initial processing step performed to reduce subsequent computational and storage requirements. In this paper, a beamspace algorithm is presented that computes the compressive spatial spectrum from conventional beamformer output power. Results from CALOPS-07 experiment will be presented and shown to significantly reduce the computational load as well as increase robustness when detecting low SNR targets. [This work was supported by ONR.]

9:30

3aSPa5. Experimental investigations on coprime microphone arrays for direction-of-arrival estimation. Dane R. Bush, Ning Xiang (Architectural Acoust., Rensselaer Polytechnic Inst., 2609 15th St., Troy, NY 12180, danebush@gmail.com), and Jason E. Summers (Appl. Res. in Acoust. LLC (ARiA), Washington, DC)

Linear microphone arrays are powerful tools for determining the direction of a sound source. Traditionally, uniform linear arrays (ULA) have inter-element spacing of half of the wavelength in question. This produces the narrowest possible beam without introducing grating lobes—a form of aliasing governed by the spatial Nyquist theorem. Grating lobes are often undesirable because they make direction of arrival indistinguishable among their passband angles. Exploiting coprime number theory, however, an array can be arranged sparsely with fewer total elements, exceeding the aforementioned spatial sampling limit separation. Two sparse ULA sub-arrays with coprime number of elements, when nested properly, each produce narrow grating lobes that overlap with one another exactly in just one direction. By combining the sub-array outputs it is possible to retain the shared beam while mostly canceling the other superfluous grating lobes. This work implements two coprime microphone arrays with different lengths and sub-array spacings. Experimental beam patterns are shown to correspond with simulated results even at frequencies above and below the array's design frequency. Side lobes in the directional pattern are inversely correlated with bandwidth of analyzed signals.

9:45

3aSPa6. Shallow-water waveguide invariant parameter estimation and source ranging using narrowband signals. Andrew Harms (Elec. and Comput. Eng., Duke Univ., 129 Hudson Hall, Durham, NC 27708, andrew.harms@duke.edu), Jonathan Odom (Georgia Tech Res. Inst., Durham, North Carolina), and Jeffrey Krolik (Elec. and Comput. Eng., Duke Univ., Durham, NC)

This paper concerns waveguide invariant parameter estimation using narrowband underwater acoustic signals from multiple sources at known range, or alternatively, the ranges of multiple sources assuming known waveguide invariant parameters. Previously, the waveguide invariant has been applied to estimate the range or bottom properties from intensity striations observed from a single broadband signal. The difficulty in separating striations from multiple broadband sources, however, motivates the use of narrowband components, which generally have higher signal-to-noise ratios and are non-overlapping in frequency. In this paper, intensity fluctuations of narrowband components are shown to be related across frequency by a time-warping (i.e., stretching or contracting) of the intensity profile, assuming constant radial source velocity and the waveguide invariant β. A maximum likelihood estimator for the range with β known or for the invariant parameter β with known source range is derived, as well as Cramer-Rao bounds on estimation accuracy assuming a Gaussian noise model. Simulations demonstrate algorithm performance for constant radial velocity sources in a representative shallow-water ocean waveguide. [Work supported by ONR.]

WEDNESDAY MORNING, 29 OCTOBER 2014 — INDIANA G, 10:15 A.M. TO 12:00 NOON

Session 3aSPb

Signal Processing in Acoustics: Spectral Analysis, Source Tracking, and System Identification (Poster Session)

R. Lee Culver, Chair

ARL, Penn State University, PO Box 30, State College, PA 16804

All posters will be on display from 10:15 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 10:15 a.m. to 11:00 a.m. and contributors of even-numbered papers will be at their posters from 11:00 a.m. to 12:00 noon.

Contributed Papers

3aSPb1. Improvement of the histogram in the degenerate unmixing estimation technique algorithm. Junpei Mukae, Yoshihisa Ishida, and Takahiro Murakami (Dept. of Electronics and Bioinformatics, Meiji Univ., 1-1-1 Higashi-mita, Tama-ku, Kawasaki-shi 214-8571, Japan, ce41094@meiji.ac.jp)

A method of improving the histogram in the degenerate unmixing estimation technique (DUET) algorithm is proposed. The DUET algorithm is one of the methods of blind signal separation (BSS). The BSS framework is to retrieve source signals from mixtures of them without a priori information about the source signals and the mixing process. In the DUET algorithm, the histogram of both the direction-of-arrivals (DOAs) and the distances is formed from the mixtures which are observed using two sensors. And then, signal separation is achieved using time-frequency masking based on the histogram. Consequently, the capability for the DUET algorithm strongly depends on the performance of the histogram. In general, the histogram is degraded by the reverberation or the reflection of the source signals when the DUET algorithm is applied in the real environment. Our approach is to

improve the histogram of the DUET algorithm. In our method, the phase component of the observed mixture at each frequency bin is modified by those at the neighboring frequency bins. The proposed method gives the sharper histogram in comparison with the conventional approach.

3aSPb2. Start point estimation of a signal in a frame. Anri Ota (Dept. of Electronics and Bioinformatics, Meiji Univ., 1-1-1 Higashi-mita, Tama-ku, Kawasaki-shi 214-8571, Japan, ce41017@meiji.ac.jp), Yoshihisa Ishida, and Takahiro Murakami (Dept. of Electronics and Bioinformatics, Meiji Univ., Kawashiki-shi, Japan)

An algorithm for start-point estimation of a signal from a frame is presented. In many applications of speech signal processing, the signal to be processed is often segmented into several frames, and then the frames are categorized into speech and non-speech frames. Instead, we focus on only the frame in which the speech starts. To simplify the problem, we assume that the speech is modeled by a number of complex sinusoidal signals. When a complex sinusoidal signal that starts in a frame is observed, it can be modeled as multiplication of a complex sinusoidal signal of which the length is infinite and a window function that has finite duration in the time domain. In the frequency domain, the spectrum of the signal of the frame is given by the shifted spectrum of the window function. Sharpness of the spectrum of the window function depends on the start point of the signal. Hence, the start point of the signal is estimated by the sharpness of the observed spectrum. This approach can be extended to the signal that consists of a number of complex sinusoidal signals. Simulation results using artificially generated signals show the validity of our method.

3aSPb3. Examination and development of numerical methods and algorithms designed for the determination of an enclosure's acoustical characteristics via the Schroeder Function. Miles Possing (Acoust., Columbia College Chicago, 1260 N Dearborn, 904, Chicago, IL 60610, miles@possing.com)

A case study was conducted to measure the acoustical properties of a church auditorium. While modeling the project using EASE 2.1, some problems arose when attempting to determine the reverberation time using the Schroder Back Integrated Impulse Function within EASE 2.1. An auxiliary investigation was launched aiming to better understand the Schroeder algorithm in order to produce a potentially improved version in MATLAB. It was then theorized that the use of a single linear regression is not sufficient to understand the nature of the decay, due to the non-linearity of the curve, particularly during the initial decay. Rather, it is hypothesized that the use of numerical methods to find instantaneous rates of change over the entire initial decay along with a Savitsky-Golay Filter could possibly yield much more robust, accurate results when attempting to derive the local reverberation time from reflectogram data.

3aSPb4. A modified direction-of-arrival estimation algorithm for acoustic vector sensors based on Unitary Root-MUSIC. Junyuan Shen, Wei Li, Yuanming Guo, and Yongjue Chen (Electronics and Commun. Eng., Harbin Inst. of Technol., XiLi University Town HIT C#101, Shenzhen, GuangDong GD 755, China, Juny_Shen@hotmail.com)

A novel method applying for direction-of-arrival(DOA) using acoustic vector sensors(AVS) based on Unitary Root-MUSIC algorithm(URM) is proposed in this paper. AVS array has a characteristic named coherence principle of sound pressure and velocity, which can significantly improve the detection performance of DOA by reducing the influence of white Gaussian noise. We apply this characteristic and the extra velocity information of AVS to construct a modified covariance matrix. In particular, the modified covariance matrix need not extend the dimension in calculation of AVS covariance matrix which means saving the computing time. In addition, we combine the characteristics of modified matrix with URM algorithm to design a new algorithm, which can minimize the impact of environment noise and further reduce computational complexity to a lower order of magnitude. So the proposed method can not only improve the accuracy of DOA detection but also reduce the computational complexity, compared to the classic DOA algorithm. Theory analysis and simulation experiment show that the proposed algorithm for AVS based on URM can significantly improve the DOA resolution in low SNR ratios and few snapshots.

3aSPb5. Multiple pitch estimation using comb filters considering overlap of frequency components. Kyohei Tabata, Ryo Tanaka, Hiroki Tanji, Takahiro Murakami, and Yoshihisa Ishida (Dept. of Electronics and Bioinformatics, Meiji Univ., 1-1-1 Higashimita, Tama-ku, Kawasaki-shi, Kanagawa 214-8571, Japan, ce31063@meiji.ac.jp)

We propose a method of the multiple pitch estimation using the comb filters for transcript. We can know the pitches of a musical sound by detecting the bigger outputs in comb filters connected in parallel. Each comb filter has peak corresponding to each pitch and its harmonic frequencies. The outputs of the comb filters corresponding to input pitch frequencies have bigger frequency components, and show bigger outputs than other comb filter's ones. However, when there is the fundamental frequency of higher tone near harmonics of lower tones, the pitch estimation often fails. Therefore, the estimation is assigned to a wrong note when frequency components are shared. The proposed method estimates the correct pitch by correcting the outputs using the matrix, which is defined as the power ratio of the harmonic frequencies to the fundamental frequency. The effectiveness of our proposed method is confirmed by simulations. The proposed method enables more accurate pitch estimation than other conventional methods.

3aSPb6. Evaluating microphones and microphone placement for signal processing and automatic speech recognition of teacher-student dialog. Michael C. Brady, Sydney D'Mello, Nathan Blanchard (Comput. Sci., Univ. of Notre Dame, Fitzpatrick Hall, South Bend, IN 46616, mbrady8@nd.edu), Andrew Olney (Psych., Univ. of Memphis, Memphis, TN), and Martin Nystrand (Education, English, Univ. of Wisconsin, Madison, WI)

We evaluate a variety of audio recording techniques for a project on the automatic analysis of speech dialog in middle school and high school classrooms. In our scenario, the teacher wears a headset microphone or a lapel microphone. A second microphone is then used to collect speech and related sounds from students in the classroom. Various boundary microphones, omni-directional microphones, and cardioid microphones are tested as this second classroom microphone. A commercial microphone array [Microsoft Xbox Kinect] is also tested. We report on how well digital source-separation techniques work for segregating the teacher and student speech signals from one another based on these various microphones and placements. We also test the recordings using various automatic speech recognition engines for word recognition error rates under different levels of background noise. Preliminary results indicate one boundary microphone, the Crown PZM-30, to be superior for the classroom recordings. This is based on its performance at capturing near and distant student signals for ASR in noisy conditions, as measured by ASR error rates across different ASR engines.

Session 3aUW

Underwater Acoustics, Acoustical Oceanography, Animal Bioacoustics, and ASA Committee on Standards: Standardization of Measurement, Modeling, and Terminology of Underwater Sound

Susan B. Blaeser, Cochair
Acoustical Society of America Standards Secretariat, 1305 Walt Whitman Road, Suite 300, Melville, NY 11747

Michael A. Ainslie, Cochair
Underwater Tech. Dept., TNO, P.O. Box 96864, The Hague 2509JG, Netherlands

George V. Frisk, Cochair
Dept. of Ocean Eng., Florida Atlantic Univ., Dania Beach, FL 33004-3023

Chair's Introduction—9:00

Invited Papers

9:05

3aUW1. Strawman outline for a standard on the use of passive acoustic towed arrays for marine mammal monitoring and mitigation. Aaron Thode (SIO, UCSD, 9500 Gilman Dr., MC 0238, La Jolla, CA 92093-0238, athode@ucsd.edu)

There is a perceived need from several U.S. federal agencies and departments to develop consistent standards for how passive acoustic monitoring (PAM) for marine mammals is implemented for mitigation and regulatory monitoring purposes. The use of towed array technology is already being required for geophysical exploration activities in the Atlantic Ocean and the Gulf of Mexico. However, to date no specific standards have been developed or implemented for towed arrays. Here, a strawman outline for a ANSI standard is presented (http://wp.me/P4j34t-a) to cover requirements and recommendations for the following aspects of towed array operations: initial planning (including guidelines for when PAM is not appropriate), hardware, software, and operator training requirements, real-time mitigation and monitoring procedures, and required steps for performance validation. The outline scope, at present, does not cover operational shutdown decision criteria, sound source verification, or defining the required detection range of the system. Instead of specifying details of towed array systems, the current strategy is to focus on the process of defining the required system performance for a given application, and then stepping through how the system hardware, software, and operations should be selected and validated to meet or exceed these requirements. [Work supported by BSEE.]

9:30

3aUW2. Towards a standard for the measurement of underwater noise from impact pile driving in shallow water. Peter H. Dahl (Appl. Phys. Lab. and Mech. Eng. Dept., Univ. of Washington, Mech. Eng., 1013 NE 40th St., Seattle, WA 98105, dahl@apl.washington.edu), Pete D. Theobald, and Stephen P. Robinson (National Physical Lab., Children's Respiratory and Critical Care Specialists, PA, Middlesex, United Kingdom)

Measurements of the underwater noise field from impact pile driving are essential to the address environmental regulations in effect in both Europe and North America to protect marine life. For impact pile driving in shallow water there exists a range scale $R^* = H/\tan(\Theta)$ that delineates important features in the propagation of underwater sound from impact pile driving, where Θ is the Mach angle of the wavefront radiated into the water from the pile and H is water depth. This angle is about 17o for many steel piles typically used, and thus R^* is approximately 3H. For range R, such that $R/R^* \sim 0.5$ depth variation in the noise field is highest, more so with peak pressure than with sound exposure level (SEL); for $R/R^* > 1$ the field becomes more uniform with depth. This effect of measurement range can thus have implications on environmental monitoring designed to obtain a close-range datum, which is often used with a transmission loss model to infer the noise level at farther range. More consistent results are likely obtained if the measurement range is at least 3H. Ongoing standardization activities for the measurement and reporting of sound levels radiated from impact pile driving will also be discussed.

9:55

3aUW3. Importance of metrics standardization involving the effects of sound on fish. Michele B. Halvorsen (CSA Ocean Sci. Inc, 8502 SW Kansas Hwy, Stuart, FL 34997, mhalvorsen@conshelf.com)

Reporting accurate metrics while employing good measurement practices is a topic that is gaining awareness. Seemingly a simple and expected task, however when reading current and past literature, reporting sound metrics utilized is often not met. It is clear that increased awareness and development of standardization of acoustic metrics is necessary. When reviewing previously published literature on the effects of sound on fish, it is often difficult to fully understand how metrics were calculated leaving the reader to make assumptions. Furthermore, the lack of standardization and definition decreases the amount of data and research studies that could be directly comparable. In a field that has paucity of effects of sound on fish, this situation underscores the importance and need for standardization.

10:20

3aUW4. Developments in standards and calibration methods for hydrophones and electroacoustic transducers for underwater acoustics. Stephen P. Robinson (National Physical Lab., National Physical Lab., Hampton Rd., Teddington TW11 0LW, United Kingdom, stephen.robinson@npl.co.uk), Kenneth G. Foote (Woods Hole Oceanographic Inst., Woods Hole, MA), and Pete D. Theobald (National Physical Lab., Teddington, United Kingdom)

If they are to be meaningful, underwater acoustic measurements must be related to common standards of measurement. In this paper, a description is given of the existing standards for the calibration of hydrophones and electroacoustic transducers for underwater acoustics. The description covers how primary standards are currently realized and disseminated, and how they are validated by international comparisons. A report is also given of the status of recent developments in specification standards, for example within the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). The discussion focuses on the revision of standards for transducer calibration, and the inclusion of extended guidance on uncertainty assessment, and on the criteria for determining the locations of the acoustic near-field and far-field. A description is then provided of recent developments using non-traditional techniques such as optical sensing, which may lead to the next generation of standards. A report is also given of the status of recent developments in and of a number of current initiatives to promote best measurement practice.

Contributed Papers

10:45

3aUW5. All clicks are not created equally: Variations in high-frequency acoustic signal parameters of the Amazon river dolphin (*Inia geoffrensis*). Marie Trone (Math and Sci., Valencia College, 1800 Denn John Ln., Kissimee, FL 34744, mtronedolphin@yahoo.com), Randall Balestriero (Université de Toulon, La Garde, France), Hervé Glotin (Université de Toulon, Toulon, France), and Bonnett E. David (None, None, Silverdale, WA)

The quality and quantity of acoustical data available to researchers are rapidly increasing with advances in technology. Recording cetaceans with a 500 kHz sampling rate provides a more complete signal representation than traditional sampling at 96 kHz and lower. Such sampling provides a profusion of data concerning various parameters, such as click duration, interclick intervals, frequency, amplitude, and phase. However, there is disagreement in the literature in the use and definitions of these acoustic terms and parameters. In this study, Amazon River dolphins (*Inia geoffrensis*) were recorded using a 500 kHz sampling rate in the Peruvian Amazon River watershed. Subsequent spectral analyses, including time waveforms, fast Fourier transforms and wavelet scalograms, demonstrate acoustic signals with differing characteristics. These high frequency, broadband signals are compared, and differences are highlighted, despite the fact that currently an unambiguous way to describe these acoustic signals is lacking. The need for standards in cetacean bioacoustics with regard to terminology and collection techniques is emphasized.

11:00

3aUW6. Acoustical terminology in the *Sonar Modelling Handbook*. Andrew Holden (Dstl, Dstl Portsdown West, Fareham PO17 6AD, United Kingdom, apholden@dstl.gov.uk)

The UK *Sonar Modelling Handbook* (SMH) defines the passive and active Sonar Equations, and their individual terms and units, which are extensively used for sonar performance modelling. The new Underwater Acoustical Terminology ISO standard, which is currently being developed by the ISO working group TC43/SC3/WG2 to standardize terminology will have an impact on the SMH definitions. Work will be presented comparing the current SMH terminology with both the future ISO standard and other well-known definitions to highlight the similarities and differences between each of these.

11:15

3aUW7. The definitions of "level," "sound pressure," and "sound pressure level" in the International System of Quantities, and their implications for international standardization in underwater acoustics. Michael A. Ainslie (Acoust. and Sonar, TNO, P.O. Box 96864, The Hague 2509JG, Netherlands, michael.ainslie@tno.nl)

The International System of Quantities (ISQ), incorporating definitions of physical quantities and their units, was completed in 2009 following an extensive collaboration between two major international standards organizations, the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). The ISQ encompasses all SI units as well as selected units outside the SI such as the byte (including both decimal and binary multiples), bel, neper, and decibel. The ISQ, which includes definitions of the terms "level," "sound pressure," and "sound pressure level," is presently being used to underpin an underwater acoustics terminology standard under development by ISO. For this purpose, pertinent ISQ definitions are analyzed and compared with alternative standard definitions, and with conventional use of the same terms. The benefits of combining IEC and ISO definitions into a single standard, solving some longstanding problems, are described. The comparison also reveals some teething problems, such as internal inconsistencies within the ISQ, and discrepancies with everyday use of some of the terms, demonstrating the need for continued collaboration between the major standards bodies. As of 2014, the ISQ is undergoing a major revision, leading to a unique opportunity to resolve these discrepancies.

Session 3pAA

Architectural Acoustics: Architectural Acoustics Medley

Norman H. Philipp, Chair
Geiler & Associates, 1840 E. 153rd Circle, Olathe, KS 66062

Contributed Papers

1:00

3pAA1. From the sound up: Reverse-engineering room shapes from sound signatures. Willem Boning and Alban Bassuet (Acoust., ARUP, 77 Water St., New York, NY 10005, willem.boning@arup.com)

Typically, architects and acousticians design rooms for music starting from a model room shape known from past experience to perform well acoustically. We reverse the typical design process by using a model sound signature to generate room shapes. Our method builds off previous research on reconstructing room shapes from recorded impulse responses, but takes an instrumental, design-oriented approach. We demonstrate how an abstract sound signature constructed in a hybrid image source-statistical acoustical simulator can be translated into a room shape with the aid of a parametric design interface. As a proof of concept, we present a study in which we generated a series of room shapes from the same sound signature, analyzed them with commercially available room acoustic software, and found objective parameters for comparable receiver positions between shapes to be within just-noticeable-difference ranges of each other.

1:15

3pAA2. Achieving acoustical comfort in restaurants. Paul Battaglia (Architecture, Univ. at Buffalo, 31 Rose Ct Apt. 4, Snyder, NY 14226, plb@buffalo.edu)

The achievement of a proper acoustical ambiance for restaurants has long been described as a problem of controlling noise to allow for speech intelligibility among patrons at the same table. This simplification of the acoustical design problem for restaurants does not entirely result in achieving either a sensation of acoustical comfort or a preferred condition for social activity sought by architects. In order to more fully study the subjective impression of acoustical comfort a large data base from 11 restaurants with 75 patron surveys for each (825 total) was assembled for analysis. The results indicate that a specific narrow range of reverberation time can produce acoustical comfort for restaurant patrons of all ages. Other physical and acoustical conditions of the dining space are shown to have little to no consistent effect on the registration of comfort. The results also indicate that different subjective components of acoustical comfort—quietude, communication, privacy—vary significantly by age group with specific consequences for the acoustical design of restaurants for different clienteles.

1:30

3pAA3. 500-seat theater in the city of Qom; Computer simulation vs. acoustics measurements. Hassan Azad (Architecture, Univ. of Florida, 3527 SW, 20th Ave., 1132B, Gainesville, FL 32607, h.azad@ufl.edu)

There is an under construction 500-seat Theater in Qom city in Iran in which I was part of the acoustics design team. We went through a different steps of the acoustics design using Odeon software packages which enabled us to go back and forth in design process and make proper improvement while we were suffering from having limitations on material choice. Fortunately the theater is being built so after a while it would be feasible to do acoustics measurements with the help of Building and Housing Research Center (BHRC) in Iran as well as subjective evaluation during the very first performances. This paper is aimed to juxtapose the results of computer simulation and acoustics measurement and make a comparison in between to see if there are any discrepancies.

1:45

3pAA4. Acoustical materials and sustainability analyses. Hassan Azad (Architecture, Univ. of Florida, 3527 SW, 20th Ave., 1132B, Gainesville, FL 32607, h.azad@ufl.edu)

Acoustical materials can perform a variety of functions from absorption and diffusion to the insulation and noise control. They may have similar acoustical performance but very different characteristics in terms of sustainability. It is important to evaluate the environmental effects of materials which exhibit the same acoustical performance in order to wisely choose the best alternative available. This study is intended to introduce and compare the different tools and methods which are commonly used in environmental sustainability analysis of materials including Eco-profile, Eco-indicator, Eco-invent, and also software packages like IMPACT. Also, a specific kind of computer model is proposed in which one can run process of calculation of both acoustics properties and sustainability assessment of a given material through computer aided techniques. The model consists of a simple cubic room with a given set of materials for its elements like walls, floor, ceiling, and windows or doors (if any). The acoustics properties which can be calculated are reverberation time with the help of either Odeon or Catt-Acoustics Software and Air borne/impact sound insulation with the help of recently developed software, SonArchitect. For the sustainability assessment both LCA method and software packages like IMPACT are the main tools.

2:00

3pAA5. Influence of the workmanship on the airborne sound insulation properties of light weight building plasterboard steel frame wall systems. Herbert Muellner (Acoust. and Bldg. Phys., Federal Inst. of Technol. TGM Vienna, Wexstrasse 19-23, Vienna A-1200, Austria, herbert.muellner@tgm.ac.at) and Thomas Jakits (Appl. Res. and Development, Saint-Gobain Rigips Austria GesmbH, Vienna, Austria)

Building elements which are built according to the light weight mode of construction, e.g. plasterboard steel frame wall systems show a large variation of air borne sound insulation properties although the elements appear as identical. According to several studies conducted in the recent years, certain aspects of workmanship have significant influence on the air borne sound insulation characteristics of light weight building elements. The method to fasten the planking (e.g., gypsum boards, gypsum fiber boards) as well as the number and position of the screws can lead to considerable variations regarding the sound insulation properties. Above 200 Hz, the sound reduction index R can differ more than 10 dB by the variation of the position of the screws. Applying prefabricated composite panels of adhesive connected plasterboards not only considerably reduces the depth of the dip of the critical frequency caused by the higher damping due to the interlayer but it can also significantly decrease the negative influence of the workmanship on the air borne sound insulation properties of these kinds of light weight walls in comparison to the standard planking of double layer plasterboard systems. The influence of secondary construction details and workmanship will be discussed in the paper.

2:15

3pAA6. Contribution of floor treatment characteristics to background noise levels in health care facilities, Part 1. Adam L. Paul, David A. Arena, Eoin A. King, Robert Celmer (Acoust. Prog. & Lab, Univ. of Hartford , 200 Bloomfield Ave., West Hartford, CT 06117, celmer@hartford.edu), and John J. LoVerde (Paul S. Veneklasen Res. Foundation, Santa Monica, CA)

Acoustical tests were conducted on five types of commercial-grade flooring to assess their potential contribution to noise generated within health care facilities outside of patient rooms. The floor types include sheet vinyl (with and without a 5 mm rubber backing), virgin rubber (with and without a 5 mm rubber backing), and a rubber-backed commercial grade carpet for comparison. The types of acoustical tests conducted were ISO-3741 compliant sound power level testing (using two source types: a tapping machine to simulate footfalls and a rolling hospital cart), and sound absorption testing as per ASTM-C423. Among the non-carpet samples, the material type that produced the least sound power was determined to be the rubber-backed sheet vinyl. While both 5 mm-backed samples showed a significant difference compared to their un-backed counterparts with both source types, the rubber-backed sheet vinyl performed slightly better than the rubber-backed virgin rubber in the higher frequency bands in both tests. The performance and suitability of these flooring materials in a health care facility compared to commercial carpeting will be discussed. [Work supported by Paul S. Veneklasen Research Foundation.]

2:30

3pAA7. Visualization of auditory masking for firefighter alarm detection. Casey Farmer (Dept. of Mech. Eng., Univ. of Texas at Austin, 1208 Enfield Rd., Apt. 203, Austin, TX 78703, caseymfarmer@utexas.edu), Mustafa Z. Abbasi, Preston S. Wilson (Appl. Res. Labs, Dept. of Mech. Eng., Univ. of Texas at Austin, Austin, TX), and Ofodike A. Ezekoye (Dept. of Mech. Eng., Univ. of Texas at Austin, Austin, TX)

An essential piece of firefighter equipment is the Personal Alert Safety System (PASS), which emits an alarm when a firefighter has been inactive for a specified period of time and is used to find and rescue downed firefighters. The National Institute for Occupational Safety and Health (NIOSH) firefighter fatality reports suggest that there have been instances when the PASS alarm is not audible by other firefighters on the scene. This paper seeks to use acoustic models to measure the sound pressure level of various signals throughout a structure. With this information, a visual representation will be created to map where a PASS alarm is audible and where it is masked by noise sources. This paper presents an initial audibility study, including temporal masking and frequency analysis. The results will be compared to auralizations and experimental data. Some other potential applications will be briefly explored.

2:45

3pAA8. Investigations on acoustical coupling within single-space monumental structures using a diffusion equation model. Zühre Sü Gül (R&D / Architecture, MEZZO Studyo / METU, METU Technopolis KOSGEB-TEKMER No112, ODTU Cankaya, Ankara 06800, Turkey, zuhre@mezzostudyo.com), Ning Xiang (Graduate Program in Architectural Acoust., School of Architecture, Rensselaer Polytechnic Inst., Troy, NY), and Mehmet Čalışkan (Dept. of Mech. Eng., Middle East Tech. Univ. / MEZZO Studyo, Ankara, Turkey)

Sound energy distributions and flows within single-space rooms can be exploited to understand the occurrence of multi-slope decays. In this work, a real-size monumental worship space is selected for investigations of non-exponential sound energy decays. Previous field tests in this single-space venue indicate multi-slope formation within such a large volume and the multiple-dome upper structure layout. In order to illuminate/reveal the probable reasons of non-exponential sound energy decays within such an architectural venue, sound energy distributions and energy flows are investigated. Due to its computational efficiency and advantages in spatial energy density and flow vector analysis, a diffusion equation model (DEM) is applied for modeling sound field of the monumental worship space. Preliminary studies indicate good agreement for overall energy decay time estimations among experimental field and DEM results. The energy flow vector and energy distribution analysis indicate the upper central dome-structure to be the potential energy accumulation/ concentration zone, contributing to the later energy decays.

WEDNESDAY AFTERNOON, 29 OCTOBER 2014 INDIANA A/B, 1:00 P.M. TO 3:20 P.M.

Session 3pBA

Biomedical Acoustics: History of High Intensity Focused Ultrasound

Lawrence A. Crum, Cochair
Applied Physics Laboratory, University of Washington, Center for Industrial and Medical Ultrasound, Seattle, WA 98105

Narendra T. Sanghvi, Cochair
R & D, SonaCare Medical, 4000 Pendleton way, Indianapolis, IN 46226

Invited Papers

1:00

3pBA1. History of high intensity focused ultrasound, Bill and Frank Fry and the Bioacoustics Research Laboratory. William O'Brien and Floyd Dunn (Elec. Eng., Univ. of Illinois, 405 N. Mathews, Urbana, IL 61801, wdo@uiuc.edu)

1946 is a key year in the history of HIFU. That year, sixty-eight years ago, the Bioacoustics Research Laboratory was established at the University of Illinois. Trained in theoretical physics, William J, (Bill) Fry (1918–1968) left his graduate studies at Penn State University to work at the Naval Research Laboratory in Washington, DC on underwater sound during World War II. Bill was hired by the

University of Illinois in 1946, wanting to continue to conduct research activities of his own choosing in the freer university atmosphere. Like Bill, Francis J. (Frank) Fry (1920–2005) went to Penn State as well as the University of Pittsburgh where he studied electrical engineering. Frank joined Bill at the University of Illinois, also in 1946, having worked at Westinghouse Electric Corporation where his division was a prime contractor on the Manhattan Project. Floyd Dunn also arrived at the University of Illinois in 1946 as an undergraduate student, having served in the European Theater during World War II. The talk will recount some of the significant HIFU contributions that emerged from BRL faculty, staff, and students. [NIH Grant R37EB002641.]

1:20

3pBA2. Transforming ultrasound basic research in to clinical systems. Narendra T. Sanghvi and Thomas D. Franklin (R & D, SonaCare Medical, 4000 Pendleton way, Indianapolis, IN 46226, narensanghvi@sonacaremedical.com)

In late 1960s, Robert F. Heimburger, MD, Chief of Neurosurgery at Indiana University School of Medicine, started collaborating with William J. Fry and Francis J. Fry at Interscience Research Institute (IRI) in Champaign, IL. and treated brain cancer patients with HIFU. In 1970, Dr. Heimburger and Indiana University School of Medicine (IUMS) invited IRI to join IUMS and Indianapolis Center For Advanced Research, Inc. (ICFAR). In 1972, a dedicated Fortune Fry Research Laboratory (FFRL) was inaugurated to advance ultrasound research relevant for clinical use. In the '70s, an automated computer controlled, integrated B-mode, image-guided HIFU system ("the candy machine") was developed that successfully treated brain cancer patients at IUMS. HIFU was found to be safe for the destruction of brain tumors. Later a second-generation brain HIFU device was developed to work with CAT or MR images. In 1974, the FFRL developed a first cardiac real-time, 2-D ultrasound scanner. Prof. H. Feigenbaum pioneered this imaging technique and formed "Echocardigraphy Society." In 1978, an automated breast ultrasound system was successfully developed led to form Labsonics, Inc. that proliferated 300 scanners in 4 years. In 1986, the Sonablate system to treat prostate cancer was developed. The Sonablate has been used worldwide.

1:40

3pBA3. The development of high intensity focused ultrasound in Europe, what could we have done better? Gail ter Haar (Phys., Inst. of Cancer Res., Phys. Dept., Royal Marsden Hospital, Sutton, Surrey SM2 5PT, United Kingdom, gail.terhaar@icr.ac.uk)

The clinical uptake of HIFU has been disappointingly slow. This despite its promise as a minimally invasive, ultimately conformal technique. It may be instructive to look at the way in which this technique has evolved from its early days with an eye as to whether a different approach might have resulted in its more rapid acceptance. Examples will be drawn from HIFU's development in the United Kingdom.

2:00

3pBA4. LabTau's experience in therapeutic ultrasound : From lithotripsy to high intensity focused ultrasound. Jean-Yves Chapelon, Michael Canney, David Melodelima, and Cyril Lafon (U1032, INSERM, 151 Cours Albert Thomas, Lyon 69424, France, jean-yves.chapelon@inserm.fr)

Research on therapeutic ultrasound at LabTau (INSERM Lyon, France) began in the early 1980s with work on shock waves that lead to the development of the first ultrasound-guided lithotripter. In 1989, this research shifted towards new developments in the field of HIFU with applications in urology and oncology. The most significant developments have been obtained in urology with the Ablatherm™ project, a transrectal HIFU device for the thermal ablation of the prostate. This technology has since become an effective therapeutic alternative for patients with localized prostate cancer. Since 2000, three generations of the Ablatherm™ have been CE marked and commercialized by EDAP-TMS. The latest version, the FocalOne™, allows for the focal treatment of prostate cancer and combines dynamic focusing and fusion of MR images to ultrasound images acquired in real time by the imaging probe integrated in the HIFU transducer. Using toroidal ultrasound transducers, a HIFU device was also recently validated clinically for the treatment of liver metastases. Another novel application that has reached the clinic is for the treatment of glaucoma using a miniature, disposable HIFU device. Today, new approaches are also being investigated for treating cerebral and cardiac diseases.

2:20

3pBA5. High intensity therapeutic ultrasound research in the former USSR in the 1950s–1970s. Vera Khokhlova (Dept. of Acoust., Phys. Faculty, Moscow State Univ., 1013 NE 40th St., Seattle, Washington 98105, va.khokhlova@gmail.com), Valentin Burov (Dept. of Acoust., Phys. Faculty, Moscow State Univ., Moscow, Russian Federation), and Leonid Gavrilov (Andreev Acoust. Inst., Moscow, Russian Federation)

A historical overview of therapeutic ultrasound research performed in the former USSR in the 1950s–1970s is presented. In the 1950s, the team of A.K.Burov in Moscow proposed the use of non-thermal, non-cavitational mechanisms of high intensity unfocused ultrasound to induce specific immune responses in treating Brown Pearce tumors in an animal model and melanoma tumors in a number of patients. Later, in the early 1970s, new studies began at the Acoustics Institute in Moscow jointly with several medical institutions. Significant results included first measurements of cavitation thresholds in animal brain tissues *in vivo* and demonstration of the feasibility to apply high intensity focused ultrasound (HIFU) for local ablation of brain structures through the intact skull. Another direction was ultrasound stimulation of superficial and deep receptors in humans and animals using short HIFU pulses; these studies became the basis for ultrasound stimulation of different neural structures and have found useful clinical applications for diagnostics of skin, neurological, and hearing disorders. Initial studies on the synergism between ultrasound in therapeutic doses combined with consecutive application of ionizing radiation were carried out. Later, hyperthermia research was also performed for brain tissues and for ophthalmology. [Work supported by the grant RSF 14-12-00974.]

2:40

3pBA6. The development of MRI-guided focused ultrasound at Brigham & Women's Hospital. Nathan McDannold (Radiology, Brigham and Women, 75 Francis St, Boston, MA MA, njm@bwh.harvard.edu)

The Focused Ultrasound Laboratory was created in the Department of Radiology at Brigham & Women's Hospital in the early 1990's, when Ferenc Jolesz invited Kullervo Hynynen to join him to collaborate with GE Medical Systems to develop MRI-guided Focused Ultrasound surgery. This collaboration between Dr. Hynynen, an experienced researcher of therapeutic ultrasound, Dr. Jolesz, who developed MRI-guided laser ablation, and the engineers at GE and later InSightec, with their decades of experience developing MRI and ultrasound systems, established a program that over two decades produced important contributions to HIFU. In this talk, Nathan McDannold, the current director of the laboratory, will review the achievements made by the team of researchers, which include the development of the first MRI-guided FUS system, the creation of the first MRI-compatible phased arrays, important contributions to the validation and implantation of MR temperature mapping and thermal dosimetry, the development of an MRI-guided transcranial system, and the discovery that ultrasound and microbubbles can temporarily disrupt the blood–brain barrier. This output of this team, which led to clinical systems that have treated tens of thousands of patients at sites around the world, is an excellent example of how academic research can be to the clinic.

3:00

3pBA7. What have we learned about shock wave lithotripsy in the past thirty years? Pei Zhong (Mech. Eng. and Mater. Sci., Duke Univ., 101 Sci. Dr., Durham, NC 27708, pzhong@duke.edu)

Shock wave lithotripsy (SWL) has revolutionized the treatment of kidney stone disease since its introduction in the early 1980s. Considering the paucity of knowledge about the bioeffects of shockwaves in various tissues and renal concretions 30 years ago, the success of SWL is a truly remarkable fest on its own. We have learned a lot since then. New technologies have been introduced for shock wave generation, focusing, and measurement, among others. In parallel, new knowledge has been acquired progressively about the mechanisms of stone comminution and tissue injury. Yet there are still outstanding issues that are constantly debated, waiting for resolution. In this talk, the quest for a better understanding of the shockwave interaction with stones and renal tissue in the field of SWL will be reviewed in chronological order. Focus will be on stress waves and cavitation for their distinctly different (for their origin), yet often synergistically combined (in their action), roles in the critical processes of SWL. This historical review will be followed by a discussion of the recent development and future prospects of SWL technologies that may ultimately help to improve the clinical performance and safety of contemporary shock wave lithotripters. [Work supported by NIH through 5R37DK052985-18.]

WEDNESDAY AFTERNOON, 29 OCTOBER 2014 INDIANA C/D, 2:00 P.M. TO 3:05 P.M.

Session 3pED

Education in Acoustics: Acoustics Education Prize Lecture

Uwe J. Hansen, Chair
Chemistry & Physics, Indiana State University, 64 Heritage Dr, Terre Haute, IN 47803-2374

Chair's Introduction—2:00

Invited Paper

2:05

3pED1. Educating mechanical engineers in the art of noise control. Colin Hansen (Mech. Eng., Univ. of Adelaide, 33 Parsons St., Marion, SA 5043, Australia, chansen@bigpond.net.au)

Acoustics and noise control is one of the disciplines where the material that students learn during a well-structured undergraduate course, can be immediately applied to many problems that they may encounter during their employment. However, in order to find optimal solutions to noise control problems, it is vitally important that students have a good fundamental understanding of the physical principles underlying the subject as well as a good understanding of how these principles may be applied in practice. Ideally, they should have access to affordable software and be confident in their ability to interpret and apply the results of any computer-based modelling that they may undertake. Students must fully understand any ethical issues that may arise, such as their obligation to ensure their actions do not contribute to any negative impact on the health and welfare of any communities. How do we ensure that our mechanical engineering graduates develop the understanding and knowledge required to tackle noise control problems that they may encounter after graduation? This presentation attempts to answer this question by discussing the process of educating undergraduate and postgraduate mechanical engineering students at the University of Adelaide, including details of lab classes, example problems, text books and software developed for the dual purpose of educating students and being useful in assisting graduates solve practical noise control problems.

Session 3pID

Interdisciplinary: Hot Topics in Acoustics

Paul E. Barbone, Chair
Mechanical Engineering, Boston University, 110 Cummington St, Boston, MA 02215

Chair's Introduction—1:00

Invited Papers

1:05

3pID1. Online education: From classrooms to outreach, the internet is changing the way we teach and learn. Michael B. Wilson (Phys., North Carolina State Univ., 1649 Highlandon Ct, State College, PA 16801, wilsomb@gmail.com)

The internet is changing the face of education in the world today. More people have access to more information than ever before, and new programs are organizing and providing educational content for free to millions of internet users worldwide. This content ranges from interesting facts and demonstrations that introduce a topic to entire university courses. Some of these programs look familiar and draw from the media and education of the past, building off the groundwork laid by television programs like Watch Mr. Wizard, Bill Nye the Science Guy, and Reading Rainbow, with others more reminiscent of traditional classroom lectures. Some programs, on the other hand, are truly a product of modern internet culture and fan communities. While styles and target audiences vary greatly, the focus is education, clarifying misconceptions, and sparking an interest in learning. Presented will be a survey of current online education, resources, and outreach, as well as the state of acoustics in online education.

1:35

3pID2. Advanced methods of signal processing in acoustics. R. Lee Culver (School of Architecture, Rensselaer Polytechnic Inst., State College, Pennsylvania) and Ning Xiang (School of Architecture, Rensselaer Polytechnic Inst., Greene Bldg., 110 8th St., Troy, NY 12180, xiangn@rpi.edu)

Signal processing is applied in virtually all areas of modern acoustics to extract, classify, and/or quantify relevant information from acoustic measurements. Methods range from classical approaches based on Fourier and time-frequency analysis, to array signal processing, feature extraction, computational auditory scene analysis, and Bayesian inference, which incorporates physical models of the acoustic system under investigation together with advanced sampling techniques. This talk highlights new approaches to signal processing recently applied in a broad variety of acoustical problems.

2:05

3pID3. Hot topics in fish acoustics (active). Timothy K. Stanton (Dept. Appl. Ocean. Phys. & Eng., Woods Hole Oceanographic Inst., Woods Hole, MA 02543, tstanton@whoi.edu)

It is important to quantify the spatial distribution of fish in their natural environment (ocean, lake, and river) and how the distribution evolves in time for a variety of applications including (1) management of fish stocks to maintain a sustainable source of food and (2) to improve our understanding of the ecosystem (such as how climate change impacts fish) through quantifying predator–prey relationships and other behavior. Active fish acoustics provides an attractive complement to nets given the great distances sound travels in the water and its ability to rapidly survey a large region at high resolution. This method involves studying distributions of fish in the water through analyzing their echoes through various means. While this field has enjoyed development for decades, there remain a number of "hot topics" receiving attention from researchers today. These include: (1) broadband acoustics as an emerging tool for advanced classification of, and discrimination between, species, (2) multi-beam imaging systems used to classify fish schools by size and shape, (3) long-range (km to 10's km) detection of fish, and (4) using transmission loss to classify fish on one-way propagation paths. Recent advances in these and other topics will be presented.

Session 3pNS

Noise: Sonic Boom and Numerical Methods

Jonathan Rathsam, Cochair
NASA Langley Research Center, MS 463, Hampton, VA 23681

Alexandra Loubeau, Cochair
NASA Langley Research Center, MS 463, Hampton, VA 23681

Contributed Papers

1:00

3pNS1. Source parameters for the numerical simulation of lightning as a nonlinear acoustic source. Andrew Marshall, Neal Evans, Chris Hackert, and Karl Oelschlaeger (Southwest Res. Inst., 6220 Culebra Rd., San Antonio, TX 78238-5166, andrew.marshall@swri.org)

Researchers have proposed using acoustic data to obtain additional insight into aspects of lightning physics. However, it is unclear how much information is retained in the nonlinear acoustic waveform as it propagates and evolves away from the lightning channel. Prior research in tortuous lightning has used simple N-waves as the initial acoustic emission. It is not clear if more complex properties of the lightning channel physics are also transmitted in the far-field acoustic signal, or if simple N-waves are a sufficient source term to predict far-field propagation. To investigate this, the authors have conducted a numerical study of acoustic emissions from a linear lightning channel. Using a hybrid strong-shock/weak-shock code, the authors compare the propagation of a simple N-wave and emissions from a source derived from simulated strong shock waves from the lightning channel. The implications of these results on the measurement of sound from nearby lightning sources will be discussed.

1:15

3pNS2. Nearfield acoustic measurements of triggered lightning using a one-dimensional microphone array. Maher A. Dayeh and Neal Evans (Southwest Res. Inst., Div 18, B77, 6220 Culebra Rd., San Antonio, TX 78238, neal.evans@swri.org)

For the first time, acoustic signatures from rocket-triggered lightning are measured by a 15 m long, one-dimensional microphone array consisting of 16 receivers, situated 79 m from the lightning channel. Measurements were taken at the International Center for Lightning Research and Testing (ICLRT) in Camp Blanding, FL, during the summer of 2014. We describe the experimental setup and report on the first observations obtained to date. We also discuss the implications of these novel measurements on the thunder initiation process and its energy budget during lightning discharges. Challenges of obtaining measurements in these harsh ambient conditions and their countermeasures will also be discussed.

1:30

3pNS3. The significance of edge diffraction in sonic boom propagation within urban environments. Jerry W. Rouse (Structural Acoust. Branch, NASA Langley Res. Ctr., 2 North Dryden St., MS 463, Hampton, VA 23681, jerry.w.rouse@nasa.gov)

Advances in aircraft design, computational fluid dynamics, and sonic boom propagation modeling suggest that commercial supersonic aircraft can be designed to produce quiet sonic booms. Driven by these advances the decades-long government ban on overland supersonic commercial air transportation may be lifted. The ban would be replaced with a noise-based certification standard, the development of which requires knowledge of community response to quiet sonic booms. For inner city environments the estimation of community exposure to sonic booms is challenging due to the complex topography created by buildings, the large spatial extent and the required frequency range. Such analyses are currently intractable for traditional wave-based numerical methods such as the Boundary Element Method. Numerical methods based upon geometrical acoustics show promise, however edge diffraction is not inherent in geometrical acoustics and may be significant. This presentation shall discuss an initial investigation into the relative importance of edge diffraction in inner city sound fields caused by sonic booms. Results will provide insight on the degree to which edge diffraction effects are necessary for accurate predictions of inner city community exposure.

1:45

3pNS4. Sonic boom noise exposure inside homes. Jacob Klos (Structural Acoust. Branch, NASA Langley Res. Ctr., 2 N. Dryden St., MS 463, Hampton, VA 23681, j.klos@nasa.gov)

Commercial supersonic overland flight is presently banned both nationally and internationally due to the sonic boom noise that is produced in overflown communities. However, within the next decade, NASA and industry may develop and demonstrate advanced supersonic aircraft that significantly mitigate the noise perceived at ground level. To allow commercial operation of such vehicles, bans on commercial supersonic flight must be replaced with a noise-based certification standard. In the development of this standard, variability in the dose-response model needs to be identified. Some of this variability is due to differing sound transmission characteristics of homes both within the same community and among different communities. A tool to predict the outdoor-to-indoor low-frequency noise transmission into homes has been developed at Virginia Polytechnic Institute and State University, which was used in the present study to assess the indoor exposure in two communities representative of the northern and southern United States climate zones. Sensitivity of the indoor noise level to house geometry and material properties will be discussed. Future plans to model the noise exposure variation among communities within the United States will also be discussed.

2:00

3pNS5. Evaluation of the effect of aircraft size on indoor annoyance caused by sonic booms. Alexandra Loubeau (Structural Acoust. Branch, NASA Langley Res. Ctr., MS 463, Hampton, VA 23681, a.loubeau@nasa.gov)

Sonic booms from recently proposed supersonic aircraft designs developed with advanced tools are predicted to be quieter than those from previous designs. The possibility of developing a low-boom flight demonstration vehicle for conducting community response studies has attracted international interest. These studies would provide data to guide development of a preliminary noise certification standard for commercial supersonic aircraft. An affordable approach to conducting these studies suggests the use of a

sub-scale experimental aircraft. Due to the smaller size and weight of the sub-scale vehicle, the resulting sonic boom is expected to contain spectral characteristics that differ from that of a full-scale vehicle. To determine the relevance of using a sub-scale aircraft for community annoyance studies, a laboratory study was conducted to verify that these spectral differences do not significantly affect human response. Indoor annoyance was evaluated for a variety of sonic booms predicted for several different sizes of vehicles. Previously reported results compared indoor annoyance for the different sizes using the metric Perceived Level (PL) at the exterior of the structure. Updated results include analyses with other candidate noise metrics, nonlinear regression, and specific boom duration effects.

2:15

3pNS6. Effects of secondary rattle noises and vibration on indoor annoyance caused by sonic booms. Jonathan Rathsam (NASA Langley Res. Ctr., MS 463, Hampton, VA 23681, jonathan.rathsam@nasa.gov)

For the past 40 years, commercial aircraft have been banned from overland supersonic flight due to the annoyance caused by sonic booms. However, advanced aircraft designs and sonic boom prediction tools suggest that significantly quieter sonic booms may be achievable. Additionally, aircraft noise regulators have indicated a willingness to consider replacing the ban with a noise-based certification standard. The outdoor noise metric used in the certification standard must be strongly correlated with indoor annoyance. However, predicting indoor annoyance is complicated by many factors including variations in outdoor-to-indoor sound transmission and secondary indoor rattle noises. Furthermore, direct contact with vibrating indoor surfaces may also affect annoyance. A laboratory study was recently conducted to investigate candidate noise metrics for the certification standard. Regression analyses were conducted for metrics based on the outdoor and transmitted indoor sonic boom waveforms both with and without rattle noise, and included measured floor vibration. Results indicate that effects of vibration are significant and independent of sound level. Also, the presence or absence of rattle sounds in a transmitted sonic boom signal generally changes the regression coefficients for annoyance models calculated from the outdoor sound field, but may not for models calculated from the indoor sound field.

2:30

3pNS7. Artificial viscosity in smoothed particle hydrodynamics simulation of sound interference. Xu Li, Tao Zhang, YongOu Zhang (School of Naval Architecture and Ocean Eng., Huazhong Univ. of Sci. and Technol., Wuhan, Hubei Province 430074, China, lixu199123@gmail.com), Huajiang Ouyang (School of Eng., Univ. of Liverpool, Liverpool, United Kingdom), and GuoQing Liu (School of Naval Architecture and Ocean Eng., Huazhong Univ. of Sci. and Technol., Wuhan, Hubei Province, China)

The artificial viscosity has been widely used in reducing unphysical oscillations in the Smoothed Particle Hydrodynamics (SPH) simulations. However, the effects of artificial viscosity on the SPH simulation of sound interference have not been discussed in existing literatures. This paper analyzes the effects and gives some suggestions on the choice of computational parameters of the artificial viscosity in the sound interference simulation. First, a standard SPH code for simulating sound interference in the time domain is built by solving the linearized acoustic wave equations. Second, the Monaghan type artificial viscosity is used to optimize the SPH simulation. Then the SPH codes with and without the artificial viscosity are both used to simulate the sound interference and the numerical solutions are compared with the theoretical results. Finally, different values of computational parameters of the artificial viscosity are used in the simulation in order to determine the appropriate values. It turns out that the numerical solutions of SPH simulation of sound interference agree well with the theoretical results. The artificial viscosity can improve the accuracy of the sound interference simulation. The appropriate values of computational parameters of the artificial viscosity are recommended in this paper.

2:45

3pNS8. Smoothed particle hydrodynamics simulation of sound reflection and transmission. YongOu Zhang (School of Naval Architecture and Ocean Eng., Huazhong Univ. of Sci. and Technol., Wuhan 430074, China, zhangyo1989@gmail.com), Tao Zhang (School of Naval Architecture and Ocean Eng., Huazhong Univ. of Sci. and Technol., Wuhan, Hubei Province, China), Huajiang Ouyang (School of Eng., Univ. of Liverpool, Liverpool, United Kingdom), and TianYun Li (School of Naval Architecture and Ocean Eng., Huazhong Univ. of Sci. and Technol., Wuhan, China)

Mesh-based methods are widely used in acoustic simulations nowadays. However, acoustic problems with complicated domain topologies and multiphase systems are difficult to be described with these methods. On the contrary, Smoothed Particle Hydrodynamics (SPH), as a Lagrangian method, does not have much trouble in solving these problems. The present paper aims to simulate the reflection and transmission of sound waves with the SPH method in time domain. Firstly, the linearized acoustic equations are represented in the SPH form by using the particle approximation. Then, one dimensional sound reflection and transmission are simulated with the SPH method and the solutions are compared with the theoretical results. Finally, the effects of smoothing length and neighboring particle numbers on the computation are discussed. The errors of sound pressure, particle velocity, and change of density show that the SPH method is feasible in simulating the reflection and transmission of sound waves. Meanwhile, the relationship between the characteristic impedance and the reflected waves obtained by the SPH simulation is consistent with the theoretical result.

3:00

3pNS9. A high-order Cartesian-grid finite-volume method for aeroacoustics simulations. Mehrdad H. Farahani (Head and Neck Surgery, UCLA, 31-24 Rehab Ctr., UCLA School of Medicine, 1000 Veteran Ave., Los Angeles, CA 90095, mh.farahani@gmail.com), John Mousel (Mech. and Industrial Eng., The Univ. of Iowa, Iowa City, IA), and Sarah Vigmostad (Biomedical Eng., The Univ. of Iowa, Iowa City, IA)

A moving-least-square based finite-volume method is developed to simulate acoustic wave propagation and scattering from complicated solid geometries. This hybrid method solves the linearized perturbed compressible equations as the governing equations of the acoustic field. The solid boundaries are embedded in a uniform Cartesian grid and represented using level set fields. Thus, the current approach avoids unstructured grid generation for the irregular geometries. The desired boundary conditions are imposed sharply on the immersed boundaries using a ghost fluid method. The scope of the implementation of the moving moving-least-square approach in the current solver is threefold: reconstruction of the field variables on cell faces for high-order flux construction, population of the ghost cells based on the desired boundary condition, and filtering the high wave number modes near the immersed boundaries. The computational stencils away from the boundaries are identical; hence, only one moving-least-square shape-function is computed and stored with its underlying grid pattern for all the interior cells. This feature significantly reduces the memory requirement of the acoustic solver compared to similar finite-volume method on irregular unstructured mesh. The acoustic solver is validated against several benchmark problems.

Session 3pUW

Underwater Acoustics: Shallow Water Reverberation I

Dajun Tang, Chair
Applied Physics Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105

Chair's Introduction—1:00

Invited Papers

1:05

3pUW1. Overview of reverberation measurements in Target and Reverberation Experiment 2013. Jie Yang, Dajun Tang, Brian T. Hefner, Kevin L. Williams (Appl. Phys. Lab, Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, jieyang@apl.washington.edu), and John R. Preston (Appl. Res. Lab., Penn State Univ., State College, PA)

The Target and REverberation EXperiment 2013 (TREX13) was carried out off the coast of Panama City, Florida, from 22 April to 16 May, 2013. Two fixed-source/fixed-receiver acoustic systems were used to measure reverberation over time under diverse environmental conditions, allowing study of reverberation level (RL) dependence on bottom composition, sea surface conditions, and water column properties. Beamformed RL data are categorized to facilitate studies emphasizing (1) bottom reverberation; (2) sea surface impact; (3) biological impact; and (4) target echo. This presentation is an overview of RL over the entire experiment, summarizing major observations and providing a road map and suitable data sets for follow-up efforts on model/data comparisons. Emphasis will be placed on the dependence of RL on local geoacoustic properties and sea surface conditions. [Work supported by ONR.]

1:25

3pUW2. Non-stationary reverberation observations from the shallow water TREX13 reverberation experiments using the FORA triplet array. John R. Preston (ARL, Pennsylvania State Univ., P. O. Box 30, MS3510, State College, PA 16804, jrp7@arl.psu.edu), Douglas A. Abraham (CausaSci LLC, Ellicott City, MD), and Jie Yang (APL, Univ. of Washington, Seattle, WA)

A large experimental effort called TREX13 was conducted in April-May 2013 off Panama City, Florida. As part of this effort, reverberation and clutter measurements were taken in a fixed-fixed configuration in very shallow water (~20 m) over a 22 day period. Results are presented characterizing reverberation, clutter and noise in the 1800-5000 Hz band. The received data are taken from the triplet subaperture of the Five Octave Research Array (FORA). The array was fixed 2 m off the sea floor and data were passed to a nearby moored ship (the R/V Sharp). An ITC 2015 source transducer was fixed 1.1 m off the seafloor nearby. Pulses comprised of gated CWs and LFMs were used in this study. Matched filtered polar plots of the reverberation and clutter are presented using the FORA triplet beamformer. There are clear indications of biologic scattering. Some of the nearby shipwrecks are clearly visible in the clutter, as are reflections from a DRDC air-filled hose. The noise data show a surprising amount of time-dependent anisotropy. Some statistical characterization of these various components of the reverberation are presented using K-distribution based algorithms to note differences in the estimated shape parameter. Help from the Applied Physics Laboratory at the University of Washington was crucial to this effort. [Work supported by ONR code 322OA.]

Contributed Paper

1:45

3pUW3. Propagation measurement using source tow and moored vertical line arrays during TREX13. William S. Hodgkiss, David Ensberg (Marine Physical Lab, Scripps Inst. of Oceanogr., La Jolla, CA), and Dajun Tang (Appl. Phys. Lab, Univ of Washington, 1013 NE 40th St., Seattle, WA 98105, djtang@apl.washington.edu)

The objective of TREX13 (Target and Reverberation EXperiment 2013) is to investigate shallow water reverberation by concurrently measuring propagation, local backscatter, and reverberation, as well as sufficient environmental parameters needed to achieve unambiguous model/data comparison. During TREX13 the Marine Physical Laboratory (MPL) conducted propagation and forward scatter measurements. The MPL effort during TREX13 included deploying three, 32-element (0.2 m element spacing), vertical line arrays along the Main Reverberation Track at a bearing of ~128° and ranges ~2.4 km, ~4.2 km, and ~0.5 km from the R/V Sharp, where reverberation measurements were being made. In addition, MPL carried out repeated source tows in the band of 2–9 kHz along the Main Reverberation Track, using tonal and LFM waveforms. The experimental procedure is described and the resulting source-tow data is examined in the context of Transmission Loss and its implications for reverberation.

Invited Papers

2:00

3pUW4. Comparison of signal coherence for continuous active and pulsed active sonar measurements in littoral waters. Paul C. Hines (Dept. of Elec. and Comput. Eng., Dalhousie Univ., PO Box 15000, Halifax, NS B3H 4R2, Canada, phines50@gmail.com), Stefan M. Murphy (Defence R&D Canada, Dartmouth, NS, Canada), and Keaton T. Hicks (Dept. of Mech. Eng., Dalhousie Univ., Halifax, NS, Canada)

Military sonars must detect, localize, classify, and track submarine threats from distances safely outside their circle of attack. However, conventional pulsed active sonars (PAS) have duty cycles on the order of 1% which means that 99% of the time, the track is out of date. In contrast, continuous active sonars (CAS) have a 100% duty cycle, which enables continuous updates to the track. This should significantly improve tracking performance. However, one would typically want to maintain the same bandwidth for a CAS system as for the PAS system it might replace. This will provide a significant increase in the time-bandwidth product, but may not produce the increase in gain anticipated if there are coherence limitations associated with the acoustic channel. To examine the impact of the acoustic channel on the gain for the two pulse types, an experiment was conducted as part of the Target and Reverberation Experiment (TREX) in May 2013 using a moored active sonar and three passive acoustic targets, moored at ranges from 2 to 6 km away from the sonar. In this paper, preliminary results from the experiment will be presented. [Work supported by the U.S. Office of Naval Research.]

2:20

3pUW5. Reverberation and biological clutter in continental shelf waveguides. Ankita D. Jain, Anamaria Ignisca (Mech. Eng., Massachusetts Inst. of Technol., Rm. 5-229, 77 Massachusetts Ave., Cambridge, MA 02139, ankitadj@mit.edu), Mark Andrews, Zheng Gong (Elec. & Comput. Eng., Northeastern Univ., Boston, MA), Dong Hoon Yi (Mech. Eng., Massachusetts Inst. of Technol., Cambridge, MA), Purnima Ratilal (Elec. & Comput. Eng., Northeastern Univ., Boston, MA), and Nicholas C. Makris (Mech. Eng., Massachusetts Inst. of Technol., Cambridge, MA)

Seafloor reverberation in continental shelf waveguides is the primary limiting factor in active sensing of biological clutter in the ocean for noise unlimited scenarios. The detection range of clutter is determined by the ratio of the intensity of scattered returns from clutter versus the seafloor in a resolution cell of an active sensing system. We have developed a Rayleigh-Born volume scattering model for seafloor scattering in an ocean waveguide. The model has been tested with data collected from a number of Ocean Acoustic Waveguide Remote Sensing (OAWRS) experiments in distinct US Northeast coast continental shelf environments, and has shown to provide accurate estimates of seafloor reverberation over wide areas for various source frequencies. We estimate scattered returns from fish clutter by combining ocean-acoustic waveguide propagation modeling that has been calibrated in a variety of continental shelf environments for OAWRS applications with a model for fish target strength. Our modeling of seafloor reverberation and scattered returns from fish clutter is able to explain and elucidate OAWRS measurements along the US Northeast coast.

Contributed Papers

2:40

3pUW6. Transmission loss and reverberation variability during TREX13. Sean Pecknold (DRDC Atlantic Res. Ctr., PO Box 1012, Dartmouth, NS B2Y 3Z7, Canada, sean.pecknold@drdc-rddc.gc.ca), Diana McCammon (McCammon Acoust. Consulting, Waterville, NS, Canada), and Dajun Tang (Ocean Acoust., Appl. Phys. Lab., Univ. of Washington, Seattle, WA)

The ONR-funded Target and Reverberation Experiment 2013 (TREX13) took place in the Northeastern Gulf of Mexico near Panama City, Florida, during April and May of 2013. During this trial, which took place in a shallow water (20 m deep) environment, several sets of one-way and two-way acoustic transmission loss and reverberation data were acquired. Closed form expressions are derived to trace the uncertainty in the inputs to a Gaussian beam propagation model through the model to obtain an estimate of the uncertainty in the output, both for transmission loss and for reverberation. The measured variability of the TREX environment is used to compute an estimate of the expected transmission loss and reverberation variability. These estimates are then compared to the measured acoustic data from the trial.

2:55

3pUW7. Transmission loss and direction of arrival observations from a source in shallow water. David R. Dall'Osto (Appl. Phys. Lab., Univ. of Washington, 1013 N 40th St., Seattle, WA 98105, dallosto@apl.washington.edu) and Peter H. Dahl (Appl. Phys. Lab. and Mech. Eng. Dept., Univ. of Washington, Seattle, WA)

Signals generated by the source used in the reverberation studies of the Targets and Reverberation Experiment (TREX) were recorded by a receiving array located 4.7 km downrange. The bathymetry over this range is relatively flat, with water depth 20 m. The receiving system consists of a 7-channel vertical line array, a 4-channel horizontal line array, oriented perpendicular to the propagation direction, and a 4-channel vector sensor (3-component vector and one pressure), with all channels recorded coherently recorded Transmissions were made once every 30 seconds and over a two hour recording period, changes in the frequency content, amplitude and direction were observed. As both the source and receiving array are at a fixed position in the water column, these observations are assumed to be due to changes in the environment. Interpretation of the data is given in terms of the evolving sea-surface conditions, the presence of nearby scatterers such as fish, and reflection/refraction due to the sloping shoreline.

3:10

3pUW8. Effect of a roughened sea surface on shallow water propagation with emphasis on reactive intensity obtained with a vector sensor. David R. Dall'Osto (Appl. Phys. Lab., Univ. Washington, 1013 N 40th St., Seattle, WA 98105, dallosto@apl.washington.edu) and Peter H. Dahl (Appl. Phys. Lab. and Mechanical Eng. Dept., Univ. of Washington, Seattle, WA)

In this study, sea-surface conditions during the Targets and Reverberation Experiment (TREX) are analyzed. The sea-surface directional spectrum was experimentally measured up to 0.6 Hz with two wave buoys separated by 5 km. The analysis presented here focuses on propagation relating to three canonical sea-surfaces observed during the experiment: calm conditions, and rough conditions with waves either perpendicular or parallel to the primary propagation direction. Acoustic data collected during calm and rough conditions show a significant difference in the amount of out-of-plane scattering. Interference due to this out-of-plane scattering is observed in the component of reactive intensity perpendicular to the propagation direction. These observations are compared with those generated using a model of the sea-surface scattering based on a combination of buoy-measured and modeled directional spectrum. Simulated sea-surfaces are also constructed for this numerical study. A model for wind waves is used to obtain surface wavenumbers greater than those measured by the wave buoys (~1.5 rad/m). Importantly, the spectral peak and it direction are well measured by the buoys and no assumptions on fetch are required, resulting in a more realistic wave spectrum and description of sea-surface conditions for acoustic modeling.

Plenary Session, Annual Meeting, and Awards Ceremony

Judy R. Dubno, President
Acoustical Society of America

Annual Meeting of the Acoustical Society of America

Presentation of Certificates to New Fellows

Mingsian Bai – for contributions to nearfield acoustic holography

David S. Burnett – for contributions to computational acoustics

James E. Phillips – for contributions to vibration and noise control and for service to the Society

Bonnie Schnitta – for the invention and application of noise mitigation systems

David R. Schwind – for contributions to the acoustical design of theaters, concert halls, and film studios

Neil T. Shade – for contributions to education and to the integration of electroacoustics in architectural acoustics

Joseph A. Turner – for contributions to theoretical and experimental ultrasonics

Announcements and Presentation of Awards

Presentation to Leo L. Beranek on the occasion of his 100th Birthday

Rossing Prize in Acoustics Education to Colin H. Hansen

Pioneers of Underwater Acoustics Medal to Michael B. Porter

Silver Medal in Speech Communication to Sheila E. Blumstein

Wallace Clement Sabine Medal to Ning Xiang

WEDNESDAY EVENING, 30 OCTOBER 2014 7:30 P.M. TO 9:00 P.M.

OPEN MEETINGS OF TECHNICAL COMMITTEES

The Technical Committees of the Acoustical Society of America will hold open meetings on Tuesday, Wednesday, and Thursday evenings. On Tuesday the meetings will begin at 8:00 p.m., except for Engineering Acoustics which will hold its meeting starting at 4:30 p.m. On Wednesday evening, the Technical Committee on Biomedical Acoustics will meet starting at 7:30 p.m. On Thursday evening, the meetings will begin at 7:30 p.m.

Biomedical Acoustics Indiana A/B

These are working, collegial meetings. Much of the work of the society is accomplished by actions that originate and are taken in these meetings including proposals for special sessions, workshops, and technical initiatives. All meetings participants are cordially invited to attend these meetings and to participate actively in the discussion.