Session 3aAA

Architectural Acoustics: Special Session Celebrating the Work of Russell Johnson

Damian J. Doria, Cochair
Artec Consultants, 114 W. 26th St., New York, NY 10001

William J. Cavanaugh, Cochair
Cavanaugh Tocci Assoc., Inc., 327F Boston Post Rd., Sudbury, MA 01776-3027

Chair's Introduction—8:00

Invited Papers

8:05

3aAA1. Russell Johnson: The Bolt Beranek and Newman years. William J. Cavanaugh (Cavanaugh Tocci Assoc. Inc., 327F Boston Post Rd., Sudbury, MA 01776, wcavanaugh@cavtocci.com)

In 1954, the author and Russell Johnson both joined the architectural acoustics staff of the pioneering research and consulting firm, Bolt Beranek and Newman (BBN), in Cambridge, MA. Just over 16 years later, in 1970, after exposure to some of the brightest talents in the relatively new discipline of applied acoustics, both left BBN to form their own independent consulting firms: Cavanaugh, a general consulting practice, and Johnson, which was to become an internationally renowned firm, providing comprehensive services on all phases of performance facility design including acoustics. In the mid-1990s, the author began the process of nominating his long time friend and colleague for the Acoustical Society's prestigious Wallace Clement Sabine Medal which was awarded in 1997 with the citation "for contributions to the understanding of the acoustics of performance spaces and the design of concert halls, theaters and opera houses throughout the world." This paper traces Russell Johnson's developing performance facility design interests from his early pre-WWII days, his US Army wartime service, his postwar studies at Carnegie Tech (now Carnegie Mellon University), and at Yale as well as his "extended" initial committment of two years at BBN to learn all he could about performance space acoustics.

8:25

3aAA2. Tribute to Russell Johnson: W. C. Sabine's personal paper. Leo L. Beranek (975 Memorial Dr. 804, Cambridge, MA 02138, beranekleo@ieee.org)

Russell Johnson was one of the most active acoustical consultants involved with concert hall design. He was a Senior Consultant at Bolt Beranek and Newman in Cambridge before he founded Artec. Sabine's interactions with Mr. Johnson will be featured. In 1975, the notebooks of Wallace Clement Sabine were discovered and in 1979 his consulting files were discovered. Both findings were reported [J. Acoust. Soc. Am. **61**, 629–639 (1977); J. Acoust. Soc. Am. **69**, 1–6 (1981)]. By chance, Sabine's personal papers were discovered recently and highlights from them will be presented with emphasis on his European activities from 1906 to 1917.

8:45

3aAA3. My colleague and competitor: Russell Johnson. Christopher Jaffe (Jaffe Holden Acoust., 114 A. Washington St., Norwalk, CT 06854)

This presentation documents the relationship between two architectural acoustic consultants that were active throughout the second half of the 20th century and into the 21st century. It illustrates the fact that practioners in a competive setting, devoted to the search for truth, can work together to arrive at solutions that enable a discipline to move forward.

9:05

3aAA4. Russell Johnson: Four decades of collaboration. Robert Wolff (239 Highland St., Milton, MA 02186, robertwwolff@gmail.com)

Collaboration of Russell Johnson at Bolt Beranek and Newman, Russell Johnson Associates, and Artec Consultants Inc., from 1966 to 2001, with focus on fundamental approaches to acoustics design and consulting gleaned from experiences with Russell Johnson. Insights into Johnson's beliefs about the relation of acoustics design and consulting to theater design and to buildings for the performing arts will be discussed.

9:25

3aAA5. Russell Johnson's "University of Artec". Robert Essert (Sound Space Design, 2 St. George's Court, 131 Putney Bridge Rd., London SW15 2PA, UK, bob.essert@soundspacedesign.co.uk)

Johnson's legacy was one of passion for holistic design excellence in performance buildings. Architecture and theater were early passions. His interest and skill in acoustical design was a means to influence as much as he could of the auditorium architecture because he cared about quality for the performers and audiences and also because he wanted to express his design aesthetic. I had the privilege of being at Artec from 1980 through 1996, a period when the firm outgrew the home office and emerged into the big time. Although the complexion of the firm changed over those years, Johnson's focus on quality and learning carried through. I will explore these two threads—quality and learning—as he motivated clients, architects, and the Artec staff to do excellent work, with examples of both process and creativity.

9:45

3aAA6. The Ballet Opera House competition and the New Jersey Performing Arts Center: My collaboration with Russell Johnson. Barton Myers (Barton Myers Assoc., Inc., 1025 Westwood Blvd., Los Angeles, CA 90024, mail@bartonmyers.com)

I am honored and pleased to accept Damian Doria's (ARTEC) invitation to speak about my relationship to the late Russ Johnson at the November meeting of the ASA in Miami honoring Russ. I propose to speak about my relationship as an architect working with Russ, the acoustician on two major projects: the Toronto Ballet Opera House competition (unbuilt) and the New Jersey Performing Arts Center (built). One would of course have to add to the numerous anecdotes that helped create his mythical and eccentric reputation.

10:05—10:20 Break

10:20

3aAA7. Auditorium acoustics newsletters, edited by Russell Johnson. Carl J. Rosenberg (Acentech Inc., 33 Moulton St., Cambridge, MA 02138, crosenberg@acentech.com)

From January 1968 to May 1970, Russell Johnson was the principal editor of an internal newsletter at BBN called Auditorium Acoustics. Review of the 43 extant issues presents an interesting perspective on topics of concern and interest to Johnson at that time and reflects on the public attitudes toward acoustics and concert hall design. This paper shares some of those perspectives.

10:40

3aAA8. Acoustical modeling of Russell Johnson's Singapore projects. Gary Siebein (School of Architecture, Univ. of Florida, P.O. Box 115702, Gainesville, FL 32611-5702, gsiebein@siebeinacoustic.com), Robert Lilkendey, Adam Bettcher, Threcia Robinson, and Joshua Fisher (Siebein Assoc., Inc., Gainesville, FL 32607)

The University of Florida Acoustics Lab had the pleasure of working with Russell Johnson and others at Artec in acoustical modeling of several halls, most notably, the Singapore concert and opera rooms. It was truly a pleasure to meet with the talented multidisciplinary staff that Russell put together at Artec to address the development of what can arguably be called the Concert Hall of the 21st Century: a traditional concert room that is amazingly adaptable through reverberation chambers, moving canopies, and adjustable absorption to a wide range of venues and a wide range of architectural styles. The inherently architectural and aesthetic basis Russell used to develop his style inspired a generation of architectural and acoustics students who worked on these projects with us.

11:00

3aAA9. A video retrospective of the life of Russell Johnson. Tateo Nakajima (Artec Consultants Inc., 114 West 26th St., New York, NY 10001, tn@artecconsultants.com)

A video collection of slides set to music from the life of Russell Johnson will be shown. Included are photos from early childhood provided by Johnson's sister, Barbara Mansfield. These depict background and early childhood in Pennsylvania and Johnson's military service during World War II. Later photos from Artec's archives show Johnson with colleagues, friends, and artists throughout his long career in acoustics.

11:30—12:00
Open Mic for Russell Johnson Stories

Session 3aAB

Animal Bioacoustics: Marine Mammal Acoustics in Honor of Sam Ridgway III

Dorian S. Houser, Chair
Biomimetica, 5750 Amaya Dr., #24, La Mesa, CA 91941

Invited Papers

8:00

3aAB1. Building on the shoulders of a giant: Using technology to extend biosonar research pathways first blazed by Sam H. Ridgway. Ted Cranford (Dept. of Biology, San Diego State Univ., 2674 Russmar, San Diego, CA 92123, tcranfor@mail.sdsu.edu)

Underwater biosonar research began in the middle of the last century by a handful of pioneers. Among the debates that raged in the scientific literature for the first 30 years were (1) the origin of biosonar signals and their formation into a transmitted beam and (2) the pathways and mechanisms for sound reception. Ridgway and his colleagues (1980) provided definitive proof for the nasal origin of sonar signals using electromyography and small pressure catheters inserted into various airways. Ridgway also collaborated on a series of experiments that attempted to discern the structure and function of the tympanoperiotic complex. My colleagues and I have combined remote imaging technology, high-speed video endoscopy, and finite element analysis to pinpoint the site of sonar signal generation, posit novel sound propagation pathways into and out of the heads of various odontocetes, and uncover new elements of the structure and function of the tympanoperiotic complex. These results will be presented in light of Ridgway's pioneering work.

8:20

3aAB2. Non anthropogenic deafness in marine mammals: Hearing that is going, going, gone. D. R. Ketten (Biology, WHOI, Woods Hole, MA and Harvard Med. School, Boston, MA 02114, dketten@whoi.edu), J. Arruda (WHOI, Woods Hole, MA and MEEI, Boston, MA), J. O'Malley (MEEI, Boston, MA), S. Cramer (WHOI, Woods Hole, MA), and J. Hammock (Smithsonian Inst., Washington, DC)

In humans, hearing is absent or diminished as a result of congenital defects, aging, noise exposures, traumatic events, and disease. Until concern arose about anthropogenic noise impacts on marine mammals, little was known about the mechanisms or incidence of marine mammal hearing losses. Over the past decade, we have gained substantial information from behavioral and electrophysiologic audiometres, *in vivo* imaging, and postmortem examinations. Dr. Sam Ridgway has been a pivotal element in these investigations, pioneering many of the techniques and facilitating broad collaborative studies. In this paper, the results of computerized tomographic and histologic studies of pinniped and cetacean ears, the majority of which Dr. Ridgway supplied, will be presented. The data show that marine mammals sustain precipitous and progressive hearing loss from multiple etiologies, including labyrinthitis, infestations, trauma, chronic multistage otitis, and presbycusis. In particular, older dolphins and seals develop degenerative pathologies (neural, hair cell, support cell loss, and demineralization) paralleling presbycusic changes in older humans. For captive cases, the distribution of inner ear pathologies will be compared with their premortem hearing curves to demonstrate the feasibility of back-projection hearing analyses on ears from noncaptive animals to better understand hearing status of wild populations. [Work supported by the ONR and the NIH/NIDCD]

8:40

3aAB3. Biomedical imaging for the study of auditory processes in the bottlenose dolphin. Dorian Houser (Biomimetica, 7951 Shantung Dr., Santee, CA 92071, biomimetica@cox.net), Sam Ridgway (Univ. of California, San Diego, CA 92093, ridgway@spawar.navy.mil), Patrick Moore, and James Finneran (US Navy Marine Mammal Program, San Diego, CA 92152)

The use of medical imaging techniques in marine mammalogy has traditionally consisted of anatomical investigations within *post-mortem* specimens. Within the last decade, Ridgway pioneered the use of *in vivo* scanning techniques to study physiological processes in the bottlenose dolphin. His work utilizing PET and SPECT imagings to study processes that occur during half-brain sleep and long-term persistent vigilance have opened avenues for marine mammal research not previously realized. Leveraging off of the successes of Ridgway, new work on the processing of auditory signals in the dolphin brain is underway. A dolphin is trained to perform an echolocation task while out of water. Echolocation clicks are captured at the melon surface with a suction-cup embedded hydrophone and synthetic target echoes are returned to the dolphin via a jawphone attached to the pan of the lower jaw. Under this paradigm, the dolphin performs a target discrimination task while positioned in a PET scanner. Injection of radiotracers at the time of the discrimination task will be used to map regions of blood flow and/or metabolic activity during the task. Results will provide the first visualization of regional physiological processes associated with the processing of echoic information in the dolphin brain.

9:00

3aAB4. A Forrest Gump effect? Being "there" for surprises and delights in cetacean and pinniped neurobiology. Sam Ridgway (SPAWAR Systems Ctr. San Diego, Div. 71500, 53560 Hull St., San Diego, CA 92152-5001 and School of Medicine, Univ. of California, San Diego, CA 92093)

Anaesthesia research enabled collaborations with pioneers in animal bioacoustics and neurobiology. Being "there" with Evans, Schusterman, and Scott Johnson stoked interest in hearing. Surgery on the ear with McCormick and Wever helped to elucidate sound conduction. In Wever's laboratory were also Simmons, Fay, and Saunders. (Simmons' bats were there. Bringing giant turtles and dolphins to Princeton was challenging.) With Bullock, recordings were made from auditory areas of the dolphin brain demonstrating separate centers for pulse and whistle responses. Suga helped with similar sea lion research. Sleeping seals transmitted their EEGs from pools atop Harrisons' department in Cambridge. With Woods and Galambos, far field auditory responses were characterized and correlated with the direct responses. Event-related brain potentials were also described. Discovering a deaf/mute dolphin with Don Carder and finding others with presbycusis were a surprise (ears eventually went to Ketten). Having Finneran, Schlundt, and Houser take over marine mammal TTS and sonar issues, as well as sound production work with Moore and Cranford, was delightful. There on Oahu with Mohl, Au, Nachtigall, and Supin when a baby sperm whale came onto Maui for testing again illustrated the Gump effect: "Life was like a box of chocolates. You never know what you're gonna get."

Contributed Papers

9:20

3aAB5. Estimation of the temporal structure of the echo from the fish by using the broadband sonar signal of the dolphin. Ikuo Matsuo (Dept. of Information Sci., Tohoku Gakuin Univ., Sendai 9813193, Japan, matsuo@cs.tohoku-gakuin.ac.jp), Tomohito Imaizumi, Tomonari Akamatsu (Fisheries Res. Agency, Hasaki 7620-7, Kamisu 3140408, Japan), Masahiko Furusawa (Tokyo Univ. of Marine Sci. and Technol., Minato-ku, Tokyo 1088477, Japan), Yasushi Nishimori, and Shinji Ogawa (Furuno Electric Co., Ltd., Nishinomiya 6628580, Japan)

Dolphins can identify prey by using the broadband sonar signals. Behavioral experiments indicate that dolphins can detect and discriminate targets in highly cluttered and noisy environments (Au, (1993)]. The sonar system can be improved by clarifying the ability of the dolphin and this improved sonar system is useful for fish species identification. The echo from the fish contains components resulting from multiple reflections, for example, the swim-bladder and body surface of the fish. Therefore, it is necessary to determine the distance and intensity, corresponding to the reflectivity, of these reflectors. We analyzed the echoes from fishes in seas close to Japan by using the Hilbert transform. First, we analyzed echoes which were measured from three species of the anaesthetized fish in a water tank. It was clarified that both the numbers and intensity of reflectors and the duration of the echo were varied dependent on the species, the individual, and the tilt angle. Second, we analyzed the echo which was measured from the fish suspended by nylon monofilament line in the open sea. It was clarified that the numbers and intensity of reflectors were varied dependent on the species and movement of the fish.

9:35

3aAB6. The dynamics of the bottlenose dolphin sonar beam. Josefin Starkhammar (Dept. of Elec. Measurements and Industrial Elec. Eng. and Automation, Lund Inst. of Technol. LTH, Lund Univ., Lund, Sweden, josefin.starkhammar@elmat.lth.se), Stan A. Kuczaj (Univ. of Southern Mississippi, Hattiesburg, MS), Mats Amundin (Linkoping Univ., Linkoping, Sweden), Johan Nilsson, Monica Almqvist, and Hans W. Persson (Lund Inst. of Technol. LTH, Lund Univ., Lund, Sweden)

Much research on dolphin echolocation has focused on animals that have been trained to remain stationary or to carry a device that allows the animals to move but restricts the location of the sonar beam. In such cases, a small number of hydrophones measures sonar characteristics while dolphins solve echolocation tasks. As a result, much is known about the beam axis but relatively little is known about other parts of the beam. One reason for this disparity is that it has been difficult to interpret the results from off axis measurements using a small number of hydrophones (that may or may not sample simultaneously). In this paper, we report results from a system of 47 hydrophones in a 0.75×0.75 m^2 matrix that allowed measurements to be made at multiple locations in the beam simultaneously, with a sample rate of 1 Msample/s. The system both visualizes and records echolocation clicks in real time across the whole cross section of the beam, hence allowing the full dynamics of the sonar beam to be revealed. As a demonstration of the system's utility, we present results obtained with the system to assess the acoustic properties of clicks produced spontaneously by free-swimming dolphins.

9:50—10:05 Break

10:05

3aAB7. Automated classification of frequency-modulated bowhead whale calls using contour tracing and image segmentation methods. Delphine Mathias, Aaron Thode (Scripps Inst. of Oceanogr., Marine Physical Lab., 9500 Gliman Dr. La Jolla, CA 92037-0238), Susanna B. Blackwell, Charles R. Greene, Jr., and Katherine H. Kim (Greeneridge Sci., Inc., Goleta, CA 93117)

In 2007, directional autonomous seafloor acoustic recorders (DASARs) were deployed at 35 locations over a 280 km swath in the Beaufort Sea in order to monitor potential changes in bowhead whale (*Balaena mysticetus*) locations and/or acoustic activity during seismic exploration activities. The large amount of acoustic data generated motivated the development of computer-aided methods to assist in detecting and classifying bowhead whale calls. In the classification stage, bowhead whale calls were divided into six categories: (1) upsweeps, (2) downsweeps, (3) constant calls, (4) u-shaped and (5) n-shaped undulated calls, and (6) complex calls. The frequency range, duration, and fine structure of individual calls vary considerably, creating difficulties when using match-filtering or spectrogram correlation methods. A manually reviewed test data set was assembled, containing examples from each call category, arranged by signal-to-noise ratio. The data set was then used to test several methods (based on image segmentation techniques) for extracting relevant parameters from the signal for subsequent classification. An optimization procedure was then used to generate receiver operating characteristic curves and thus determine appropriate decision boundaries for optimum statistical classifiers. [Work supported by Shell Exploration and Production Company.]

10:20

3aAB8. Automated detection and localization of nonstereotyped bowhead whale calls in the presence of seismic airgun signals, incorporating multiple directional autonomous recording packages (DASARs). Aaron Thode, Delphine Mathias (Marine Physical Lab., Scripps Inst. of Oceanogr., UCSD, La Jolla, CA 92093-0238, athode@ucsd.edu), Susanna B. Blackwell, Katherine H. Kim, and Charles R. Greene, Jr. (Greeneridge Sci. Inc., Goleta, CA 93117)

In 2007 and 2008, 35 directional autonomous recording packages (DASARs) [Greene *et al.*, J. Acoust. Soc. Am. **116**, 799–813 (2004)] were deployed at five sites over a 280 km swath in the Beaufort Sea to monitor the annual migration of the bowhead whale (*Balaena mysticetus*) population during seismic exploration activities. To expedite analysis, automated detection and localization methods are applied to each DASAR data set, employing a four-stage detection and classification algorithm. The first three stages consist of the detection phase, while the final classification stage uses image

thresholding, morphological processing, edge detection, and image segmentation to extract key features of signals from equalized spectrograms. These features are then compared to results from other DASARS at a given site in order to identify a single call across all DASARs. Bearings from each DASAR are then crossed to provide a location. Manually reviewed data sets are used to optimize the algorithm parameters for a given site and a given set of environmental conditions. The total detection and classification performance of the combined DASAR set will be compared with the performance of a single DASAR. [Work supported by Shell Exploration and Production Company.]

10:35

3aAB9. Geographic variation in northwest Atlantic fin whale (*Balaenoptera physalus*) song: Implications for stock structure assessment. Julien Delarue (College of the Atlantic, 48 N. Marriner St., South Portland, ME 04106), Sean Todd (College of the Atlantic, Bar Harbor, ME 04609), Sofie Van Parijs (Northeast Fisheries Sci. Ctr., Woods Hole, MA 02543-1026), and Lucia Di Iorio (Universitt Zurich, Rmistrasse 71, 8006 Zurich, Switzerland)

Passive acoustic data are increasingly being used as a tool for helping to define marine mammal populations and stocks. Fin whale (*Balaenoptera physalus*) songs present a unique opportunity to determine interpopulation differences. Their highly stereotyped interpulse interval has been shown to vary between geographic areas and to remain stable over time in some areas. In this study, the structure of songs recorded at two geographically close feeding aggregations in the Gulf of St. Lawrence (GSL) and Gulf of Maine (GoM) was compared. Recordings were made from September 2005 to June 2006 in the GSL and intermittently between January 2006 and September 2007 at two locations in the GoM. 6257 pulse intervals corresponding to 19 GSL and 29 GoM songs were measured to characterize songs from the three locations. Classification trees showed that GSL songs differ significantly from those in the GoM. The results are consistent with those derived from the other stock structure assessment methodologies, such as chemical signature and photoidentification analysis, suggesting that fin whales in these areas may form separate management stocks. Song structure analysis could therefore provide a useful and cost-efficient tool for defining conservation units over the temporal and geographical scales relevant to management objectives.

10:50

3aAB10. Killer whales at the Pribilof Islands: Who are they and what are they doing. Kelly Newman, Alan Springer (UAF School of Fisheries and Ocean Sci., 905 N. Koyukuk Dr., 245 O'Neill Bldg., Fairbanks, AK 99775-7220), and Craig Matkin (North Gulf Oceanic Society, Homer, AK 99603)

The Pribilof Islands, located in the eastern Bering Sea, are the site of the largest concentration of northern fur seals in the world. Despite the occurrence of transient killer whales on a near daily basis during the fur seal breeding season, these whales are unknown in terms of their social structure and overall range. Orcas were recorded with autonomous acoustic recorders at the Pribilof Islands in the summers of 2006 and 2008. This is the first study of call types and whistles of these killer whales. Whistles have been described for other odontocete species but not yet for transient killer whales. This study also reports on temporal and spatial dynamics of killer whale occurrence at the two major Pribilof Islands, St. Paul and St. George Islands. Call matches between the years and locations were analyzed to ascertain visitation patterns, predation sounds, and diurnal activity near the fur seal rookeries. Whale vocalizations from the Pribilofs were compared to other regions in Alaska. Thus far, there is no match between the calls of the Pribilof whales and those in regions of Southeast Alaska and Prince William Sound, but some calls bear a structural resemblance to calls produced by whales recorded near False Pass, AK.

11:05

3aAB11. Localization of killer whale mother, juvenile, and calf vocalizations. Dawn M. Grebner, David L. Bradley, Dean E. Capone, Susan E. Parks, Jennifer L. Miksis-Olds (Grad. Prog. in Acs., Penn State Univ., State College, PA 16804, dmg302@psu.edu), and John K. B. Ford (Pac. Biol. Station, Nanaimo, BC V9T 6N7, Canada)

A dataset of killer whale female (mother), juvenile, and calf vocalizations was collected with a hydrophone array in Johnstone Strait in the summers of 2006 and 2007. The vocalizations were spatially and temporally localized together with behavioral observations. The analysis is focused on pulsed call production variation when a mother is with her juvenile(s) and/or calf and when she is separated from one or more of them. Analysis is centered on the frequency-time structure of the vocalizations. This circumstance provides a unique opportunity to gain insight into the communication between individuals within a common social subset of a matriline or pod. This subset is characteristically tighter in association than many other intramatrilineal groups and can offer a glimpse into early vocal exchange and development.

11:20

3aAB12. Consistency of frequency dependent echolocation beam focus in an echolocating false killer whale (*Pseudorca crassidens*) performing a discrimination task. Laura Kloepper (Hawaii Inst. of Marine Biology Marine Mammal Res. Program, Dept. of Zoology, Univ. of Hawaii at Manoa, P.O. Box 1106, Kailua, HI 96734, kloepper@hawaii.edu), Stuart Ibsen (Univ. of California, San Diego, La Jolla, CA 92093), Paul Nachtigall, and Marlee Breese (Univ. of Hawaii at Manoa, Kailua, HI 96734)

Tremendous variation in individual echolocation click parameters has been shown for odontocetes, making trend analysis of individual clicks within a click train necessary to understand their generalized echolocation behavior. The frequency dependent spatial echolocation beam profile of clicks for a single false killer whale (*Pseudorca crassidens*) performing a discrimination task was collected using a star shaped 16 hydrophone array. These spatial profiles were analyzed to compare the relative spatial location and focusing of various frequencies from click to click under different target exposures. Using a go/no go paradigm, the whale actively discriminated between objects of varying transmission reflectance properties. Very tight focusing and consistent spatial location was observed for frequencies near peak frequency but deteriorated for frequencies above peak frequency. This trend did not vary between targets, suggesting that the animal maintained a constant beam focus pattern regardless of the reflection characteristics of the target. Additionally, these patterns were consistent for all clicks within a train, suggesting that the animal employs a similar beam focus pattern throughout the entire click train.

Session 3aEA

Engineering Acoustics: Acoustics for Battlefield Operations and Homeland Security I

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

Chair's Introduction—9:00

Invited Papers

9:05

3aEA1. Environmental effects on short-range acoustic propagation and sensor performance. Donald G. Albert (ERDC Cold Regions Res. and Eng. Lab., 72 Lyme Rd., Hanover, NH 03755, donald.g.albert@us.army.mil)

Autonomous passive acoustic sensor systems can potentially detect, identify, and locate sound emissions from gunfire, explosions, vehicles, and animals. However, since sound propagation through the atmosphere is influenced by many environmental conditions including meteorology, ground impedance, and barriers or obstacles, these effects need to be understood and included in sensor system design to achieve accurate performance. Low-frequency short-range measurements using impulsive sources will be presented to quantify these effects on acoustic wave form shape and amplitude attenuation. In urban areas, multiple reflections and diffractions can add enough complexity to explosion wave forms that it becomes difficult for a human listener to identify them as explosions. In these areas, classical methods to determine source locations such as beam-forming or direction-of-arrival bearing estimates from time delays can fail completely. Novel signal processing methods that incorporate the complexity of propagation in these environments can produce accurate localizations. [Work funded by U.S. Army.]

9:30

3aEA2. Orthogonal acoustic sensor package for human detection in quiet and noisy environments. James M. Sabatier and Alexander E. Ekimov (NCPA, Univ. of Mississippi, 1 Coliseum Dr., University, MS 38677)

Seismic and low-frequency acoustic sensors are severely limited by background vibrations and sound in noisy (urban) areas and a human's ability to mask the impulsive signal from his or her footsteps. Typically, noise levels are highest at low frequencies and roll off at higher frequencies. Recent research has shown that the ultrasonic signals from footsteps can be passively detected in urban areas and in buildings and are relatively independent of attempts at masking. Coupling this sensor with ultrasonic Doppler sonar and processing algorithms that tie footsteps to corresponding human motion yields an orthogonal sensor package with high probability of detection and minimal false alarms. Coupling the ultrasonic sensor package with the low-frequency traditional sensors (such as seismic sensors) forms the universal acoustic sensor package that potentially increases the probability of human detection in high-noise urban and low-noise rural environments. Successful signal processing algorithms for the sensor package are developed and tested. [Work supported by the Department of the Army, Army Research Office, Contract No. W911NF-04-1-0190.]

Contributed Papers

9:55

3aEA3. Remote detection of vehicle obscured by forest canopy using laser Doppler vibrometer. James Sabatier, Alexander Ekimov, Vyacheslav Aranchuk, and Richard Mack (NCPA, Univ. of Mississippi, 1 Coliseum Dr., University, MS 38677, sabatier@olemiss.edu)

Detection and identification of vehicles obscured by forest canopy is a particularly challenging military problem. Imaging techniques (laser radar imaging a target through gaps in foliage, for example) require extensive data, making this approach processing-intensive and time consuming. A new method for detection of a vehicle obscured by forest canopy by remotely sensing the vibration of foliage with a laser Doppler vibrometer has been proposed. The method uses the effect of coupling of sound waves from the vehicle's engine through the air to tree leaves, causing them to vibrate. The presence of a vehicle can be determined by the spectrum of the leaves' vibrations. The feasibility of the proposed method has been studied experimentally. The acoustical impedance of various types of leaves was measured in the laboratory and outdoor settings. The results show that the vibration response of a leaf to the sound from an idling vehicle is high enough to be reliably sensed with an LDV in a wide frequency band. The vibrations of leaves excited with simulated vehicle acoustic stimuli were successfully measured with an LDV in the laboratory and outdoor environment. A real vehicle masked by foliage was successfully detected by the proposed method.

10:10

3aEA4. Acoustic classification of battlefield vehicles based on their seismic detection. Peter William (Dept. of Elec. Eng., Univ. of Nebraska Lincoln, 209N WSEC, Lincoln, NE 68588, peter.ezzat@ieee.org) and Michael Hoffman (Univ. of Nebraska Lincoln, Lincoln, NE 68588)

Identification of battlefield vehicles using a wireless sensor network is an event driven application that requires simple detection and energy efficient classification. Seismic and acoustic sensors have the capability to detect and track targets in a passive non-line-of-sight manner. The proposed approach uses seismic emissions for event detection and acoustic emissions for classification of detected events. Seismic detection using unpowered geophones achieves minimal energy for wakeup and event detection in addition to elimination of wind and background noise events. Time domain extracted features from the acoustic emission of vehicles are very efficient in battlefield vehicle discrimination preserving the coupled harmonic signature for both tracked and wheeled vehicles. We propose a simple energy efficient time domain detection and classification scheme that enables the sensor node to perform detection, feature extraction, and classification. Classifica-

tion of acoustic features is performed using a multilayer feedforward neural network. The proposed approach shows that selective time domain acoustic features surpass equivalent spectral features. Evaluation of the proposed approach using recorded data shows an average classification rate (single node and single event) that exceeds 83% and an average false alarm rate of 16% (over both tracked and wheeled vehicles).

10:25

3aEA5. Localization of sources on the ground from an elevated acoustic sensor array. Vladimir E. Ostashev (NOAA/Earth System Res. Lab., Boulder, CO 80305 and Phys. Dept., New Mexico State Univ., Las Cruces, NM 88003), Michael V. Scanlon, Christian Reiff (U.S. Army Res. Lab., AMSRD-ARL-SE-SP, Adelphi, MD 20783), D. Keith Wilson, and Sergey N. Vecherin (U.S. Army Engineer Res. and Development Ctr., Hanover, NH 03755)

Acoustic sensor arrays suspended below tethered aerostats are employed for localization of sources on the ground. The aerostats can be elevated up to 1–2 km above the ground. Since the values of temperature and wind velocity vary significantly from the ground up to such heights, sound refraction should be taken into account when determining the source coordinates. Previously [Ostashev *et al.*, J. Acoust. Soc. Am. **122**, 3084 (2007)], a theory was developed that enables determination of the source coordinates from the direction of sound signal propagation as measured by the sensor array, its coordinates, and the vertical profiles of temperature and wind velocity. However, these profiles can be known only with some errors and uncertainties. In the present paper, the effects of uncertainties in the vertical profiles of temperature and wind velocity on determining the source coordinates are studied. To this end, the vertical profiles are approximated with the Monin–Obukhov theory of similarity. The uncertainties in the profiles are modeled by allowing the surface roughness length, the friction velocity, and the surface sensible heat flux vary from their mean values. Some of the results obtained are compared with experimental data.

10:40

3aEA6. Impulsive sound source localization using distributed elevated acoustic sensors. Xiao Di, Ronald Wagstaff, John Anderson, and Kenneth Gilbert (Natl. Ctr. for Physical Acoust., Univ. of Mississippi, University, MS 38677, xiaodi@olemiss.edu)

For detecting and localizing impulsive sources in the daytime, distributed elevated acoustic sensors with large base line separations have distinct advantages over small ground-based arrays. First, during the day, the signal levels are generally higher at altitude than on the ground. Second, the large base lines provide improved localization accuracy. Results are reported from a distributed array of acoustic sensors deployed during an experiment in Bourges, France during June of 2008. The distributed array consisted of microphones and global positioning system (GPS) receivers attached to the tether lines of several widely separated balloons. The sound sources were various impulsive devices. Data from the experiment are presented and discussed. In particular, the localization error is analyzed as a function of the GPS accuracy and the motion of the balloons. Possible ways to improve the localization accuracy are suggested. [Research supported by the U. S. Army TACOM-ARDEC at Picatinny Arsenal, NJ.]

WEDNESDAY MORNING, 12 NOVEMBER 2008 PLUM A & B, 8:00 TO 11:45 A.M.

Session 3aMU

Musical Acoustics and Structural Acoustics and Vibration: Structural Vibrations in Musical Instruments

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

Invited Papers

8:00

3aMU1. Modal analysis of musical instruments. Thomas Rossing (CCRMA, Dept. of Music, Stanford Univ., Stanford, CA 94305 rossing@ccrma.stanford.edu)

The complex vibrations of musical instruments can be described in terms of normal modes of vibration. Modal analysis can be done either experimentally or mathematically. We review some of the ways in which modal analysis has been successfully applied to musical instruments in the string, wind, and percussion families.

8:20

3aMU2. Applying electronic speckle pattern interferometry to the study of musical instruments. Thomas Moore (Dept. of Phys., Rollins College, Winter Park, FL 32789, tmoore@rollins.edu)

An overview of the electronic speckle pattern interferometer as a tool for the study of structural vibrations will be presented, highlighting both the theory and construction of the device. Two specific applications to the study of musical instruments will then be discussed: time-averaged interferometry of harmonic motion and time resolved interferometry of transient motion.

8:40

3aMU3. Constructing and using a low cost speckle pattern interferometer for analysis of musical instruments. Andrew Morrison (Phys. Dept., Illinois Wesleyan Univ., P.O. Box 2900, Bloomington, IL 61702-2900, achmorrison@gmail.com)

Following the design of Moore [Am. J. Phys. **72**, 1380 (2004)], a speckle-pattern interferometer for use in exploring the mode shapes of vibrating structures, especially musical instruments, has been constructed. The interferometer was built primarily by undergraduates with mostly common optical elements found in any undergraduate optics laboratory. The interferometer uses a FireWire (IEEE 1394) camera, which has a built-in frame-grabbing capability, eliminating the need for expensive frame-grabbing hardware. The interferometer has been used to study vibrating structures such as snare drum heads, mandolins, and a tennis racket. The interferometer has also been used to study the the vibrational properties of a cured carbon fiber disk. The design and implementation of an affordable speckle-pattern interferometer along with a brief overview of some of the results of research projects conducted with undergraduate students will be presented.

Contributed Papers

9:00

3aMU4. Modes of the kalimba resonator box. Daniel Ludwigsen (Dept. of Phys., Kettering Univ., 1700 W Third Ave., Flint, MI 48504)

The kalimba is an African instrument with plucked metal tines mounted on a resonator box made of hardwood. The box features both acoustic (related to air in the cavity and holes) and structural resonances. An experimental modal analysis of the box indicates some agreement between the frequencies of these structural resonances and quickly decaying spectral components of the attack. Furthermore, direct measurements of mechanical impedance at the bridge show support for the effective radiation of sound at the fundamental frequencies of the tines. A finite element model of the resonator box corroborates these results, which show several ways the design of the box affects a musical and distinctive instrument.

9:15

3aMU5. Drum tuning: An experimental analysis of membrane modes under slightly nonuniform tension. Randy Worland (Dept. of Phys., Univ. of Puget Sound, 1500 N. Warner, Tacoma, WA 98416, worland@ups.edu)

Results of an experimental study of normal mode vibrations in single-headed musical drums under nonuniform tension will be presented. Although uniform tension is often assumed in theoretical treatments, in practice the musical drum only approximates this condition, even after careful tuning by the drummer. This study investigates the behavior of normal mode shapes and frequencies under (slightly) nonuniform tension, as they relate to the tuning process. In particular, the role of the (1,1) mode will be described. Experimental results include electronic speckle pattern interferometry images of modal shapes along with the associated frequencies. A finite element model will be used for comparison with the experimental results.

Invited Papers

9:30

3aMU6. Generalized structural acoustics model of violin radiativity profiles. George Bissinger (Phys. Dept., East Carolina Univ., Greenville, NC 27858, bissingerg@ecu.edu)

Violin radiativity profiles are dominated by contributions from the Helmholtz-like *A*0 cavity mode near 280 Hz, the first corpus bending (*B*1) modes near 500 Hz, followed by a slow rise, peaking near 2.4 kHz, and a slow falloff above this peak. A blend of total damping trends, *f*-hole air motions, bridge-filter effects, bridge versus bridge-island impedances, effective critical frequencies f_{crit}, and radiation efficiency-damping trends was used to create a structural acoustics model for the entire profile. The lowest top and back plate bending modes 2 and 5 subsumed into the *B*1 modes provide nominal values for the violin f_{crit} as well as significantly influencing the *B*1 mode frequencies. *A*0 excitation via coupling of *f*-hole volume flows with those of the *B*1 modes is proposed. This coupling predicts *A*0 radiativity increasing as the *A*0-*B*1 frequency difference decreases, in accord with recent VIOCADEAS data (including violin octet experimental results) and a 1937 experiment involving too-thick/too-thin plate thickness and soundpost removal. Simplified simulations show the fraction-of-vibrational-energy-radiated F_{rad} peaking at f_{crit} (nominally coinciding with the bridge-filter peak). Dropping f_{crit} drops this peak frequency, reduces the maximum F_{rad}, and changes the relative spectral balance in vibration-acoustic energy conversion.

9:50—10:05 Break

10:05

3aMU7. Acoustic holography of musical instruments using radiation directivity method. Rolf Bader (Inst. of Musicology, Univ. of Hamburg, Neue Rabenstr. 13, 20354 Hamburg, r_bader@t-online.de)

Static and time-dependent acoustic holography is applied to the radiation of musical instruments using the acoustic camera developed at the Institute of Musicology consisting of 128 microphones simultaneously recording at a 48-kHz sample rate. Here a radiation directivity method was developed suiting the great amount of microphones as well as the high sampling frequency. It uses not only the radiation strength but also the radiation directivity pattern of 128 points on the geometry as a dependent variable. This does not only allow for a precise reconstruction of the vibration of the instruments but also results in a detailed description of the radiation directivity for the overall geometry or for each radiating point individually. Furthermore the time-dependent reconstruction avoids any temporal integration and reconstructs the vibration of the geometry with the samplerate precision. With this method the different role and strength instrument parts have in the overall body radiation, scattering effects caused by geometrical inhomogeneities, and time-dependent initial transients reconstructed as radiation patterns were investigated. The material as well as the air parts of the instrument are considered simultaneously, i.e., with guitars or violins, the enclosed air radiating through the sound holes is investigated in relation to the surrounding plates.

10:25

3aMU8. Finite element studies of hand bell modes. Uwe J. Hansen (Dept. of Chemistry Phys., Indiana State Univ., Terre Haute, IN 47809)

Hand bell modes are identified by indices m and n (m, n), where m refers to the number of nodal lines crossing the crown and n refers to the number of circumferential nodal lines. For high m values, depending on the bell size, no $n = 0$ modes exist. For such large m modes, the $n = 1$ nodal line is located very close to the mouth of the bell, rather than near the middle of the bell as is the case for $(m,1)$ modes, where for the same value of m, an $n = 0$ mode exists. These modes are generally labeled as $(m, 1^*)$ modes. Finite element studies of mode sections of increasing complexity indicate that only when two curvatures are introduced, conditions are adequate to give rise to $(m, 1^*)$ modes. Computer generated images and animations of mode patterns corresponding to increasingly complex geometries will be illustrated.

Contributed Papers

10:45

3aMU9. Radiation of guitar loudspeakers. Heiko Timm (Inst. of Musicology, Univ. of Hamburg, Neue Rabenstr. 13, 20354 Hamburg, Germany, heiko_t@web.de)

Loudspeakers of guitar amplifiers used by electric guitarists are analyzed in terms of their radiation characteristics. This was performed using an acoustic camera consisting of 128 microphones. The data recorded were digitalized with a sample rate of 48 kHz and analyzed with methods of near field acoustic holography (NAH) and statistical optimized NAH. By these algorithms an acoustic hologram was obtained. The radiation is visualized to get information about the different parts of the complete electric guitar sound box. Differences in sound between different loudspeaker constructions can be explained by taking this close look at the sound coming out of the speakers. The radiation behavior, the impulse behavior, and the diffraction of sound coming from the backside of the speaker are investigated in this way. So the amount of diffraction of sound influencing the overall character of the speaker is also addressed.

11:00

3aMU10. Measurement and modeling of the open end correction for driven pipes. Daniel Ludwigsen and Linda Hunt (Dept. of Phys., Kettering Univ., 1700 W Third Ave., Flint, MI 48504, dludwigs@kettering.edu)

The end correction that accounts for the inertial impedance at the open end of a pipe is a widely used refinement to lumped-element models, and many variations have been investigated. This study measures the end correction for 1 m closed-open pipes of varying diameters, exposed to a single-frequency external sound field created by a subwoofer in an anechoic facility. The frequency response of each pipe was measured as the ratio of the pressure at the closed end of the pipe to a reference pressure at the open end. Using an expression for the predicted mode frequencies based on the assumption that the driving pressure is uniform across the open end, the driven end correction was derived from the measured frequency response. The interaction of the pipe and the external sound field can be visualized in a finite element model, with alternative estimates of the driven end correction. Preliminary results indicate that the driven end correction can be as large as the diameter, more than three times the expected value for a passive open end.

11:15

3aMU11. Parameter estimation and inversion for wind instrument physical models. Mark Sterling, Xiaoxiao Dong, and Mark Bocko (Dept. of Elec. and Comp. Eng., Univ. of Rochester, Comput. Studies Bldg. 526, Rochester, NY 14623, sterling@ece.rochester.edu)

An outstanding goal in the field of musical instrument physical modeling has been the definition of a robust parametric and expressive representation or coding for musical audio. For this purpose, accurate dynamical models of musical instrument systems must be supported by algorithms that can provide suitable sets of control parameters for producing some desired output. We describe an estimation algorithm for clarinet physical modeling. However, the results could be applied to a broader class of convolutional wind instrument models, which fit the McIntyre–Schumacher–Woodhouse framework. Three fundamental signals in clarinet physical modeling are the blowing pressure p_m, bore pressure p_b, and flow u inside the mouthpiece. These are related via the nonlinear reed-valve characteristic and the air column impulse response. Assuming p_b is given or approximated from a digital recording using known radiation characteristics, p_m and u are iteratively estimated against one another, fitting the model to p_b. This is accomplished with an informed inversion of the reed valve and an adaptive (LMS) inverse of the bore impulse response. This method supplants prior work we have done where blowing pressure waveforms were computed by envelope detection. Results are verified with numerous audio examples. [Work partially supported by NSF Grant IIS-555457.]

11:30

3aMU12. Experimental modal study of the Kurdish long necked lute, Tanbour. Hedayat Alghassi (Dept. of Elec. and Comput. Eng., Univ. of British Columbia, Vancouver, BC V6T 1Z4, Canada), Sohrab Ferdowsi, Roozbeh Alghassi (Tehran Univ., Tehran, Iran), and Babak Khademi (Stanford Univ., Stanford, CA 94305)

This research presents the results of an experimental study of the vibration properties of the Kurdish long necked lute called Tanbour (aka Tambour, Tanbur, or Tamurah). A system transfer function of this musical instrument has been derived. [Hedayat Alghassi *et al.*, "Time series analysis of the Kurdish long necked lute Tanbour,", J. Acoust. Soc. Am. **122** (2007)]. To investigate the complex vibrational dynamics of Tanbour, the deflection patterns of Tanbour's pear shaped soundboard was acquired using a low-end time-averaged electronic speckle pattern interferometery (ESPI) imaging system. Later, the acquired image patterns were categorized as three resonance modes: near certain, dipolar, and quadrupolar. The three noticeable modes are assigned to the specific plectrum angles and positions. Moreover the short term Fourier transform (STFT) of the sound produced is derived for those plectrums. The strings were excited by a controlled mechanical plucker to maintain a high precision. Finally the sound spectra were related to the vibrational modes of the instrument, so one can approximately speculate the vibrational mode of Tanbour's soundboard from the STFT spectra for a basic plectrum.The criteria of observing three obvious vibration modes from the ESPI acquired images can also be used to achieve the optimum location of the bridge on the sound board.

Session 3aNS

Noise and Architectural Acoustics: Fire Codes and Acoustics

Matthew V. Golden, Cochair
Kinetics Noise Control, 6300 Irelan Pl., Dublin, OH 43017-0655

Ralph T. Muehleisen, Cochair
Illinois Inst. of Tech., Civil and Architectural Eng., 3201 S. Dearborn, Rm. 228, Chicago, IL 60616

Chair's Introduction—8:00

Invited Papers

8:05

3aNS1. Fire resistance and noise control in multifamily buildings. J. D. Quirt and T. R. T. Nightingale (Natl. Res. Council, Inst. for Res. in Construction, Ottawa, ON, K1A 0R6, Canada)

The walls and floors that separate dwellings in apartment buildings and condominiums must serve many functions other than structural support. To select wall or floor assemblies, designers need ready access to collections of test ratings, so this talk begins with a brief overview of some key factors affecting both the fire resistance and sound transmission ratings of wall assemblies and floor/ceiling assemblies with gypsum board surfaces. For successful buildings, however, designers must also appreciate how the overall fire resistance and sound isolation may be compromised by details at junctions and penetrations, and use a system approach that respects the requirements for both sound and fire controls. This presentation will focus on fire stops and fire blocks in the context of Canadian codes and standards, illustrate design options for fire stops at some common junctions and penetrations (mainly in the context of lightweight framed constructions), and provide guidance on corresponding acoustical issues.

8:25

3aNS2. Impact of suspended acoustical ceilings on the fire performance of open spaces. Tom Fritz and Kenneth Roy (Armstrong World Industries, ABP Technol., 2500 Columbia Ave., Lancaster, PA 17604, twfritz@armstrong.com)

An architectural design trend referred to as the "exposed structure" look is becoming increasingly popular due to a number of emerging design factors. In some cases, there is a desire to expose the overhead mechanical systems and roof deck, thus providing a feeling of spaciousness and economy. Or, in other cases, the desire for openness is driven by the installation of underfloor air distribution, in which case a traditional overhead ceiling is not needed to cover plenum mechanicals. The architects and building owners must, however, be reminded that the occupant safety, satisfaction, and performance will often be negatively impacted by these architectural design decisions. In particular, the response time of fire safety devices may be adversely affected, as shown by simulation tests.

8:45

3aNS3. Impact of material flammability regulations on acoustical treatment selection for heavy-duty vehicles. Charles Moritz, Kendall Bush, and Jennifer Shaw (Blachford Acoust. Lab., 1445 Powis Rd., West Chicago, IL 60185, cmoritz@blachfordinc.com)

Typical acoustical materials used in cars and trucks include polyurethane foam, polyester fiber blends, vinyl barriers, and various plastic or fabric facings. These materials are required to pass Federal Motor Vehicle Safety Standard 302, which regulates the speed at which a horizontal sample of the material can burn. Buses and specialty vehicles can be subject to more stringent flammability or smoke development requirements. These additional requirements may preclude the use of some common acoustical materials or require the addition of fire retardant chemicals or special facings. This paper reviews the commonly specified flammability regulations used with industrial vehicle acoustical materials and discusses their impact on material selection, performance, and cost.

9:05

3aNS4. Understanding the acoustical implications of Underwriters Laboratory listings. Matthew Golden (6300 Irelan Pl., Dublin, OH 43017, mgolden@kineticsnoise.com)

With today's ever more complicated building design, acoustical consultants should be aware of how their recommendations affect other aspects of floor/ceiling design. The acoustical ratings must be balanced with the need for fire rated assemblies as well as structural requirements. As the industry leader in the listing of fire rated designs, the Underwriters Laboratory (UL) maintains a list of assemblies that will meet various levels of fire resistance. These listings are very detailed and even slight changes to the design can have a profound impact on the assembly's fire resistance rating. This paper will compare various listed wood-frame floor/ceiling assemblies with respect to acoustical design. These comparisons will include fiberglass thickness, number of drywall layers, resilient channel spacing, and types of resilient sound clips. The general affect of each of those variables on acoustical performance will be shown. Several insights will also be shared from the acoustical supplier's perspective on the UL listing experience.

9:25

3aNS5. Gypsum board fire resistant assembly codes, standards, and certification. Rick Curkeet (Intertek Testing Services, 8431 Murphy Dr., Middleton, WI 53562, rick.curkeet@intertek.com) and John Nicholas (Intertek Testing Services, Elmendorf, TX 78112)

Fire resistant (FR) assemblies are key components of building a life safety design. These assemblies are typically required to divide buildings into smaller compartments so that, should a fire start, it will remain confined for a sufficient period to allow evacuation and arrival of fire fighting personnel. Properly installed and maintained FR construction has a long history of performance in both saving lives and limiting fire related property damage. This presentation provides an overview of the process used to develop FR assembly ratings and listings where a gypsum wallboard is a key assembly component. The discussion includes the test methods and standards required by model building codes, the process used by designers and manufacturers to obtain design certifications, and how these designs are intended to be applied in the field. There are often occasions where a basic FR assembly may need to be altered to improve performance not directly related to fire resistance. This frequently includes addition or changes in materials or other aspects of a design to improve acoustical performance. However, all changes to FR assembly designs have the potential to change the fire resistance of the assembly. The process required to obtain acceptance of design modifications is discussed.

Contributed Paper

9:45

3aNS6. The fire code and speech intelligibility. Richard J. Peppin (Scantek, Inc., 7060 Oakland Mills Rd. L, Columbia, MD 21046)

The National Fire Code has provisions for speech intelligibility for annunciators. These requirements and their measurements will be discussed.

WEDNESDAY MORNING, 12 NOVEMBER 2008 LEGENDS 10, 10:15 A.M. TO 12:00 NOON

Session 3aPA

Physical Acoustics: Material Properties and Elasticity

James P. Chambers, Chair

National Ctr. for Physical Acoustics, Univ. of Mississippi, University, MS 38677

Contributed Papers

10:15

3aPA1. Elastic constant measurements at elevated temperatures. Rasheed Adebisi and Josh Gladden (Dept. of Phys., Univ. of Mississippi, University, MS 38677)

Resonant ultrasound spectroscopy (RUS) is a technique in obtaining the full elastic tensor of single crystal materials by measuring the mechanical resonances of a polished sample. Elastic constants of materials are a sensitive probe into the atomic environment; therefore, they are useful tools for studying phase transitions at high temperatures. A high-temperature system in which test samples are in direct contact with two transducers was designed to conduct RUS measurements up to 650 °C. Extremely high-temperature (~650 °C) measurements are made possible by separating the sample, placed in a tube furnace, and the transducers with buffer rods made of low-acoustic attenuation materials with good thermal stability such as ceramic alumina or fused quartz. Results from the high-temperature measurements on a standard thermoelectric material, silicon-germanium, demonstrated that the system has the ability of acquiring resonance signals at temperatures up to 1000 °C. Experimental issues such as additional resonance peaks introduced by the buffer rods and sample loading will be addressed. The apparatus has been used to study phase transitions in transition metal oxides and novel Zintl phase thermoelectric materials. These results demonstrate the great potential of RUS methods in high-temperature physics.

10:30

3aPA2. Phononic band gaps in periodically corrugated lithium niobate plate. Igor Ostrovskii (Phys. and Astronomy, Univ. of Mississippi, University, MS 38677)

A *ZX*-cut lithium niobate crystalline plate with a periodic corrugation is shown to have the band gaps in its spectrum of the plate acoustic waves. The corrugated plate is modeled numerically using finite element method. The depth of corrugations is 20% of the plate thickness along the *Z*-axis, and the corrugation period along the *X*-axis is taken from 0.3 to 1 mm for different model samples. The phase and group velocities of propagating acoustic modes will be affected significantly by the periodic change of plate thickness. The cutoff frequencies of higher-order modes will increase, and some new plate acoustic waves will appear. The periodic corrugations will cause the reflections and band gaps in the spectra of propagating modes. The strongest effects occur when the period of corrugations is equal to an integer number of half wavelengths of a mode. However, the distortions of the spectra do not appear in the spectrum if only 10% of the plate length is corrugated. One can achieve a complete band gap with certain corrugation periods and plate thicknesses. A periodically poled corrugated $LiNbO_3$ is also considered. These acoustic properties of a phononic $LiNbO_3$ crystal may be employed in a new generation of acoustic filters.

10:45

3aPA3. Dispersion of plate acoustic waves in periodically poled lithium niobate. Andriy Nadtochiy and Igor Ostrovskii (Phys. and Astronomy, Univ. of Mississippi, University, MS 38677)

The phase and group velocity dispersion of the plate acoustic waves (PAWs) in *ZX*-cut periodically poled lithium niobate (PPLN) wafer is calculated theoretically and verified experimentally. The dispersion curves of eight lowest PAW modes are calculated with the help of the finite element method. The PAWs in PPLN have some peculiarities in comparison with the case of a single crystal waveguide. First, some PAW modes may reflect out of the multidomain structure, and so a band gap may occur in the PAW spectrum. For example, a zero antisymmetric mode *A*0 has 0.2-MHz-wide band gap at frequency where its wavelength is equal to the period of a domain pattern. Second effect includes a variation of a cutoff frequency of PAW. The experimental dispersion curves are in agreement with calculations. The phononic band gap of *A*0 mode and the cutoff frequency shift of first antisymmetric mode *A*1 are confirmed by our experiments. The

3a WED. AM

group velocity is calculated from the experimental phase-velocity dispersion curves. The calculated and measured group velocities are consistent. It is shown that the group velocity of $A0$ mode approaches zero within the band gap.

11:00

3aPA4. Large elastic softening in highly magnetostrictive Fe-based alloys. Jared LeBlanc, Gabriela Petculescu (Dept. of Phys., Univ. of Louisiana, Lafayette, LA 70504), Marilyn Wun-Fogle, James Restorff (Naval Surface Warfare Ctr., W. Bethesda, MD 20817), Thomas Lograsso (Ames Lab., Ames, IA 50011), Arthur Clark (Clark Assoc., Adelphi, MD 20783), and Kristl Hathaway (Univ. of Maryland, College Park, MD 20742)

In order to practically exploit the large magnetostriction effects observed in Fe-based alloys, the magnetoelastic interactions in these materials have to be understood. Until now, Fe–Ga alloys have exhibited the largest magnetostriction in non-rare-earth alloys, but they also present a complex phase diagram, which does not allow a simple interpretation of magnetoelastic coupling at large Ga concentrations (above 20%). Fe–Ge alloys, which show an increase in the tetragonal magnetostriction but not as pronounced as in Fe–Ga, bring, however, a cleaner and more reproducible crystalline structure for the entire range of practical compositions. Measurements of elastic constants using resonant ultrasound spectroscopy in a saturating magnetic field and as a function of temperature for different compositions of the Fe–Ge alloys will be presented and contrasted to previously published Fe–Ga results. The addition of Ge to the structure of alpha-Fe softens the $c'=(c11-c12)/2$ shear modulus significantly. For example, only with 7 at. % Ge addition, c' falls by 21% from the 48 GPa value of the pure Fe crystal.

11:15

3aPA5. Generalized acoustic cloaking theory. Andrew Norris (Dept. of Mech. and Aerosp. Eng., Rutgers Univ., Piscataway, NJ 08854, norris @rutgers.edu)

An acoustic cloak is a region enclosing an object such that acoustic waves from all directions pass through and around the cloak as though the object was not present in the fluid. The object has zero scattering strength and is therefore acoustically invisible. Several researchers have proposed using fluids with anisotropic inertia for the cloaking material, but this has been shown by the author to require a cloak with infinite mass. An alternative framework is to use pentamodal materials, which guarantees finite mass and, under certain circumstances, isotropic inertia. The acoustic cloaking theory recently proposed by the author for acoustics is but one element in a class of cloaking theories for pentamodal materials. The main result is that pentamodal materials with anisotropic inertia form an invariant set of materials under arbitrary finite deformation and under the condition that the deformed material is cloaked. The general theory is explained using the language of finite deformations, common in continuum mechanics. The group properties follow by considering finite deformation in combination with gauge transformations. The talk will attempt to explain the meaning of pentamodal materials and show that the mathematics of transformation is related to simple physical requirements of transparency.

11:30

3aPA6. Using sound radiation to study collisions in granular media. Joshua Riner, Chola Regmi, and Andi Petculescu (Dept. of Phys., Univ. of Louisiana, P.O. Box 44210, Lafayette, LA 70504)

An acoustic method to check the validity of Hertz's law and assess the actual collision force law in granular media is proposed. The technique uses a microphone to detect the sound produced by collisions between solid polypropylene balls. The impact is observed to produce an underpressure followed by an overpressure. It can be conjectured that the initial compression of the balls lowers the pressure, followed by an expansion which leads to a sharp pressure increase. The structure following the overpressure peak could be due to the bulk and surface waves produced in the spheres. There is a visible difference between the underpressure and overpressure peaks (of about 9%), which can indicate energy losses. The power spectrum has a dominant peak at ≈7 kHz, accompanied by several smaller peaks, some of which may be intermodulation products. [Work funded by the Louisiana Board of Regents.]

11:45

3aPA7. Green's function model for time-reversal focusing of elastic surface waves. Evgenia A. Zabolotskaya, Yurii A. Ilinskii, and Mark F. Hamilton (Appl. Res. Labs., The Univ. of Texas, P.O. Box 8029, Austin, TX 78713-8029)

Time-reversal focusing applied to an object buried in soil improves the ability to focus energy on the object, suggesting a promising method for mine and IED detection. As a rule, these devices are buried close to the ground surface at a depth smaller than an elastic surface wave penetration depth. A Green's function approach is used to evaluate the field scattered by the object. Both the Green's function and the source function representing the scattering site are expanded in eigenfunctions of the homogeneous wave equation. When the object is acoustically compact, the scattered wave amplitude on the surface is described in the frequency domain by a Hankel function of order zero. Below the surface, the scattered wave amplitude is described by a Bessel function of order zero multiplied by exponentials that decay with depth, plus its Hilbert transform. The Green's function in the time domain is zero for negative time, and for positive time it is the Fourier transform of the Bessel function of order zero multiplied by the exponential depth dependence. The Green's function is used twice to calculate scattering from the object, first by the probe wave and next by the time-reversed wave. [Work supported by ONR.]

Session 3aSAa

Structural Acoustics and Vibration: Building Structural Acoustics and Vibrations

Kai Ming Li, Chair
Purdue Univ., School of Mechanical Eng., Ray W. Herrick Lab., 140 Martin Jischke Dr., West Lafayette, IN 47907

Invited Papers

8:30

3aSAa1. Transmission of noise through a double-pane window. Zhaohui Yu and Kai Ming Li (Ray W. Herrick Labs., School of Mech. Eng., Purdue Univ., 140 Martin Jischke Dr., West Lafayette, IN 47907)

In the present study, the sound transmission of low-frequency noise through a double-pane window is analyzed by a coupled finite element/boundary element method (FEM/BEM). Particularly, the response of solid structure due to the acoustic excitations is treated by FEM while the behavior of fluid medium, which includes the fluid loading above and below the windows and the fluid cavity inside the window (between the double panes), is simulated by BEM. The stiffness matrix in the FEM formulation is adjusted by the technique of the component mode synthesis in order to handle the mounting conditions of windows effectively. Using the proposed model, the transmission of sound pressures through double-pane windows is calculated and validated with published experimental data. A set of comprehensive parametric studies is then conducted to explore for characterizing the acoustical properties of the double-pane windows, which may be used in the design stage.

8:50

3aSAa2. Modeling of transmission of shaped sonic booms into residential structures. Natalia Sizov, Kenneth Plotkin, and Christopher Hobbs (Wyle, 241 18th St., Ste. 701, Arlington, VA 22202, natalia.sizov@wyle.com)

The indoor perception of shaped minimized sonic booms is a concern for the acceptability of overland supersonic flight. An investigation of the transmission of shaped booms into residential structures has been conducted. Two classical methods were used. The first is single degree of freedom analysis. The second is modal analysis, modeling a wall as a simply supported rectangular panel and the interior as a rectangular cavity. Time domain responses were computed for both methods. Both methods allowed arbitrary waveforms, and the modal model allows arbitrary wave incidence angle. Sound pressures inside a room and acceleration of the wall were calculated and compared to measured data collected during the NASA sonic boom tests conducted at the Edwards Air Force Base in 2007. The effects of wave signature parameters on transmission were studied to evaluate the advantages of various kinds of low boom shapes, and the influence of thickened shock structures. Future extension of this research will be to employ finite element modeling. [This work was funded by NASA Langley Research Center, Contract No. NNL07AD96T.]

9:10

3aSAa3. Vibration and sound radiation from a rectangular panel with any boundary condition. Xuefeng Zhang and Wen L. Li (Dept. of Mech. Eng., Wayne State Univ., 5050 Anthony Wayne Dr., Detroit, MI 48202)

This presentation is concerned with the vibroacoustic analysis of rectangular panels such as building walls, which may be isotropic or anisotropic in nature. A general analytical method is first described for modeling the vibration of a panel arbitrarily supported along each of its edges. The displacement field is analytically expressed as a two-dimensional Fourier cosine series supplemented with several one-dimensional series. Mathematically, such a series expansion is capable of representing and uniformly converging to any function (including the classical solution, if exists), which is adequately smooth over the solution domain. This series solution is exact in the sense that both the governing differential equation and the boundary conditions can be satisfied, on a pointwise basis, to any specified accuracy. Once the vibration field is determined, the resulting acoustic pressure and power radiation can be calculated in a simple and systematic manner. Numerical examples are given to demonstrate the vibroacoustic effects of the panel supporting conditions.

9:30

3aSAa4. Create an audio system to sonic boom an entire house? Victor Sparrow and Steven Garrett (Grad. Prog. Acoust., Penn State Univ., 201 Appl. Sci. Bldg., University Park, PA 16802, vws1@psu.edu)

To establish thresholds of public acceptability, the Federal Aviation Administration (FAA) would like to determine if it is possible to design and build a sonic boom simulation device that can accurately reproduce a sonic boom over an entire building, or portion of a building, such as a residential home. Having such a sonic boom reproduction device would make it possible to perform subjective tests on people in their own homes when exposed to simulated sonic boom noise corresponding to aircraft that have not yet been built. This presentation describes an ongoing study directed toward the design of a simulation device that can accurately reproduce sonic booms over the entire exterior surface of a building. The authors will present some plausible strategies that are in the development stages.

However, an additional motivation for this presentation is to make ASA members aware of this research and to solicit feedback from attendees prior to a January 2009 down-selection activity for the design of a system. The strict requirements for sonic boom playback fidelity make this project a Grand Challenge in Audio Reproduction. [Work supported by the FAA through the PARTNER Center of Excellence, www.partner.aero .]

Contributed Paper

9:50

3aSAa5. Broadband duct noise attenuation by a middle-ear mechanism. Lixi Huang (Dept. of Mech. Eng., Univ. of Hong Kong, Pokfulam Rd., Hong Kong)

Low-frequency duct noise is difficult to control passively by any device limited by its total volume due to system stiffness. When a side-branch device is used, cavity air becomes incompressible toward the dc frequency. One way to tackle the relative incompressibility for low to medium frequencies is to introduce acoustic phase difference in the cavity air oscillation, which otherwise behaves like the low-order room acoustics modes. The introduction of a light plate covering the cavity in our previous studies [J. Acoust. Soc. Am. **119**, 2628–2638 (2006)] does essentially that by enhancing the non-volume-displacing modes. Optimization shows that the required stiffness-to-mass ratio is much beyond what is available for existing bulk materials. In the present study, an alternative device that resembles the ossicular structure of the mammalian middle ear is introduced. The acoustic signal is passed along through a rigid pin which simulates the ossicular bones via its longitudinal motion. Contrasting with the usual flexural waves in plate or membrane structures, the bone transmission has almost infinite speed and it creates the phase difference needed to overcome the system stiffness. Theoretical predictions show that the performance of such device is comparable and better than the idealistic plate silencer with interesting comparisons of features.

WEDNESDAY MORNING, 12 NOVEMBER 2008 LEGENDS 1, 10:15 A.M. TO 12:00 NOON

Session 3aSAb

Structural Acoustics and Vibration: Scattering and Propagation

Courtney B. Burroughs, Cochair
Pennsylvania State Univ., Applied Research Lab., P.O. Box 30, State College, PA 16804-0030

Philip L. Marston, Cochair
Washington State Univ., Physics and Astronomy Dept., Pullman, WA 99164-2814

Contributed Papers

10:15

3aSAb1. Interfacial and elastic contributions to the backscattering of a right circular cylinder: Experiments and interpretation. Jon La Follett and Philip L. Marston (Phys. and Astron. Dept., Washington State Univ., Pullman, WA 99164-2814, lafollej@mail.wsu.edu)

Synthetic aperture sonar (SAS) images of elastic targets near an interface contain features resulting from the interaction of incident and scattered sound with the interface in addition to those associated with the free-field dynamical response of the target. To improve the understanding of these features, a right circular aluminum cylinder was suspended in a water tank through an air interface and insonified at a grazing incidence. Monostatic SAS images were obtained by scanning the source (and receiver) along a horizontal line. Backscattering measurements were also made as the distance from the target to the interface was varied. Some of the features could be explained using a previously developed ray-based theory [K. Gipson and P. L. Marston, J. Acoust. Soc. Am. **106**, 1673–1680 (1999);, **107**, 112–117 (2000)]. Among these features were responses due to guided generalized Rayleigh waves such as meridional rays and helical rays. Also, ray path calculations for edge diffraction contributions (as a function of target-interface distance) were used to identify certain echoes in the SAS images. [Research supported by ONR.]

10:30

3aSAb2. Numerical study of finite-amplitude source reconstruction in one-dimension. Micah R. Shepherd, Kent L. Gee (Dept. of Phys. and Astr., Brigham Young Univ., N-283 Provo, UT 84602), and Mark S. Wochner (Univ. of Texas at Austin, Austin, TX 78713)

Since its inception in the 1980s, near-field acoustic holography (NAH) has been widely used to determine structural source properties. More recently, it has also been used to determine aeroacoustic source behavior. Although several alternate forms of NAH have been developed, all are based on the (linear) Helmholtz equation and would presumably not function correctly for a finite-amplitude pressure wave propagating nonlinearly. However, when nonlinear effects or reconstruction distances are small, NAH may still be a useful tool for determining radiation characteristics of finite-amplitude sources such as jets and rockets. A one-dimensional numerical propagation scheme has been used to propagate broadband noise with various spectral shapes and amplitudes. A simple NAH-based magnitude reconstruction is used to determine frequency-, amplitude-, and propagation distance-dependent errors indicating in what regions linear NAH methods may produce large errors. The results indicate that the presence of shock coalescence causes relatively large errors in linear sound field reconstructions of broadband noise sources.

10:45

3aSAb3. Comparison of surface velocity measurement using a scanning laser vibrometer and acoustic holography. Pawan Pingle, Scot Bruderer, Christopher Niezrecki, and Peter Avitabile (Dept. of Mech. Eng., Univ. of Massachusetts Lowell, One University Ave., Lowell, MA 01854, christopher_Niezrecki@uml.edu)

A significant amount of interest exists in performing noncontacting full-field surface velocity measurement. For many years traditional surface velocity measurements have been made by using a scanning Doppler laser vibrometer (SDLV). Nearfield acoustical holography is another approach that enables reconstruction of quantities such as the acoustic pressure, surface velocity, intensity, and power radiated from a structure into three-dimensional space, based on the sound pressure measured at a two-dimensional surface. Within this work the surface velocity of a clothes dryer

panel is computed based on the acoustic field pressure measurements by using the Helmholtz equation least square (HELS) method, in which the reconstructed sound field is optimized by using spherical wave functions. The dryer panel is measured using an SDLV as well as a 64-channel microphone array. The reconstructed full-field surface velocity using the HELS method is compared to the measurement from the laser vibrometer during operation and also at discrete resonant frequencies.

11:00

3aSAb4. Scattering of a helicoidal Bessel beam by a sphere: The effect of an azimuthal phase gradient. Philip Marston (Phys. and Astronomy Dept., Washington State Univ., Pullman, WA 99164-2814, marston@wsu.edu)

In prior work [P. L. Marston, J. Acoust. Soc. Am. **121**, 753–758 (2007)] the partial wave series for the scattering by a sphere centered on an ordinary Bessel beam was derived. The present work extends the analysis of the far field scattering to the case of a helicoidal Bessel beam having an angular phase ramp equal to the azimuthal angle. Helicoidal beams possess an axial null and have an azimuthal phase gradient. Some of the resulting modifications of the scattering are illustrated for an empty steel shell in water. In agreement with symmetry arguments given previously [B. T. Hefner and P. L. Marston, J. Acoust. Soc. Am. **106**, 3313–3316 (1999)] the backward scattering and forward scattering vanish. For some directions the scattering increases when shifting from ordinary to a helicoidal beam illumination. In addition to describing the scattering by acoustic beams, there are potential applications of this analysis to the description of acoustic radiation forces and torques. [Work supported in part by ONR and by NASA.]

11:15

3aSAb5. Pressure and displacement fields inside an absorbing fluid sphere ensonified by a plane harmonic wave. Kenneth G. Foote (Woods Hole Oceanograph. Inst., Woods Hole, MA 02543) and David T. I. Francis (Univ. of Birmingham, Edgbaston, Birmingham B15 2TT, UK)

Analytic expressions have been developed for the pressure and displacement fields and dilatation in a lossy fluid sphere due to ensonification by a plane harmonic wave in a lossy immersion medium. These quantities have been computed for a 50-mm-diameter fluid sphere in water with a density of 1000 kg/m^3 and a sound speed of 1500 m/s for each of two frequencies, 10 and 100 kHz, hence with wavenumber-radius products of order 1 and 10, respectively. The density and sound speed values in the fluid sphere have been varied to achieve contrast factors in the range of 0.5–2 relative to the respective medium property. Absorption in the fluid sphere has been varied over the range of 0–10 dB/m. Results are presented for each field quantity along the axis of the sphere, as defined by the direction of propagation of the incident wave, transverse to this axis from the center, and along the surface from the forward to reverse directions. [Work partly supported by NOPP through ONR Award No. N000140710992.]

11:30

3aSAb6. Measurement of diffracted pressure fields using an automated measurement system. Simo-Pekka Simonaho and Timo Lähivaara (Dept. of Phys., Univ. of Kuopio, P.O. Box 1627, FIN-70211 Kuopio, Finland, simo-pekka.simonaho@uku.fi)

The theory of sound diffraction has been studied widely. Different modeling methods for sound diffraction have been proposed. Some of these modeling techniques are also used in the room acoustic modeling. In this study, diffracted pressure fields from a thin panel were measured. In the measurements, a loud-speaker was used as a sound source and diffraction from a thin panel was measured. The measurements were performed in small semianechoic chamber using a three-dimensional 3-D automated position system. This system consists of a 3-D position system, a data acquisition hardware, and a control unit. With this system, it is possible to measure diffracted pressure fields with high-spatial accuracy. In addition, numerical simulations are used in the modeling of sound diffraction from a thin edge. Finally, the simulated pressure fields are compared to the measured fields.

11:45

3aSAb7. The invariants of the time-reversal operator for asymmetric response matrices. Peter Simko and Jafar Saniie (Dept. of Elec. and Comput. Eng., Illinois Inst. of Tech., 3301 S. Dearborn, Chicago, IL, psimko @ece.iit.edu)

The decomposition of the time-reversal operator is a signal analysis method applicable to ultrasonic methods of target detection and characterization. In this paper, the eigenmodes of the time-reversal operator are studied for a single rigid cylinder with elliptical cross-section leading to an asymmetric response matrix formed by the interelement response of an active transducer array. The elliptical cylinder is of considerable interest in scattering problems since it encompasses within the limit both the circular cross-section case (very low eccentricity) and the strip (eccentricity approaching infinity). Variable cylinder properties will include parameters such as cross-sectional area, eccentricity, and angle of inclination of the semimajor axis with respect to the axis of a probing transducer array. Exact solutions for determination of the far-field response matrix using the familiar modal expansion with scattering coefficients computed via Mathieu functions will be discussed. The basis functions spanning the range of the time-reversal operator under conditions for which reciprocity no longer holds will also be discussed. Theoretical analysis will indicate that for scatterers near the Rayleigh limit, it is possible to characterize the aspect ratio of the target using a subarray method.

Session 3aSC

Speech Communication: A Quantal Transition: Ken Stevens in "Retirement" I

Helen M. Hanson, Chair
Union College, Electrical and Computer Eng. Dept., 807 Union St., Schenectady, NY 12308

Chair's Introduction—8:00

Invited Papers

8:05

3aSC1. Physical principles behind quantal relations. Helen M. Hanson (ECE Dept., Union College, 807 Union St., Schenectady, NY 12308) and Kenneth N. Stevens (MIT RLE, Cambridge, MA 02139)

A distinctive contrast can be defined by a quantal relation between an articulatory parameter and an acoustic parameter. It is postulated that there are two sources of quantal relations. *Aeromechanical interactions* arise because the nature of the interaction of airflow with the compliant mechanical structures of the vocal tract can change abruptly as an articulatory parameter changes continuously. As a result, the nature of the generated acoustic source changes abruptly. *Acoustic resonator coupling* results from the fact that the vocal tract, together with adjacent structures, can create several cavities that can be coupled and uncoupled, resulting in a transfer function that can show an abrupt discontinuity as a consequence of the rapid movement of a zero. These two principles lead to a natural division of the distinctive features into two groups, articulator free and articulator bound. Because the features in the two groups are defined by different physical principles, relations among the features are quite different: the articulator-free features, being based on aerodynamic conditions in the vocal tract, are constrained hierarchically, while articulator-bound features have fewer constraints. The natural constraints among the features are such that the featural representation of a segment is rather sparse.

8:30

3aSC2. Small vocal-tract cavities revealed by magnetic resonance imaging and their acoustic influences. Kiyoshi Honda (ATR Cognit. Information Sci. Labs, 2-2-2 Hikaridai, Seika-cho, Soraku-gun, Kyoto 619-0288, Japan and Phonet. Phonology Labs, UMR7018 CNRS-Univ. Paris III, 19 rue des Bernardins, 75005 Paris, France, honda@atr.jp), Hironori Takemoto (ATR Cognit. Information Sci. Labs, Kyoto 619-0288, Japan), and Tatsuya Kitamura (Konan Univ., Kobe 658-8501, Japan)

In natural speaking conditions, the vocal tract exhibits small cavities in the hypopharyx and oral cavity, while their acoustic effects have not been fully recognized. Acoustic studies based on static and dynamic magnetic resonance imaging of the vocal tract in three dimensional have shown that these cavities cause regional resonance and antiresonance in the vocal tract. The hypopharyngeal cavities, including the supraglottal laryngeal cavity and bilateral cavities of the piriform fossa, characterize vowel spectra in the higher frequencies and contribute to determining voice quality and speaker characteristics. The laryngeal cavity functions as a Helmholtz resonator to generate an extra formant in the vicinity of 3 kHz, and the piriform fossa forms a pair of side-branches of the vocal tract to cause spectral zeros in the vicinity of 4–5 kHz. The bilateral interdental spaces form a pair of side-branches in the oral cavity in nonlow vowels, and their geometry varies with articulation. Their antiresonance frequency is below 2 kHz in /i/, while it rises toward /a/ crossing the second formant in transition, and thus causing a small discontinuity of that formant between the two vowels.

8:55

3aSC3. Subglottal coupling as a quantal basis for the feature [back]. Morgan Sonderegger (Dept. of Comput. Sci. Univ. of Chicago, 1100 E 58th St., Chicago, IL 60637, morgan@cs.uchicago.edu) and Xuemin Chi (RLE, MIT, Cambridge, MA 02139)

A model of acoustic coupling between the oral and subglottal cavities is described, which predicts attenuation of vowel formant prominences and discontinuities in formant trajectories near resonances of the subglottal system. The hypothesis that these effects on F2 near the second subglottal resonance (SubF2) are quantal effects for the feature [back] is examined using acoustic and subglottal data from English-speaking adults. Experimental studies of F2 and SubF2 in English vowel production [Chi and Sonderegger, JASA **122**, 1735–1745 (2007)] are reviewed and show that attenuation of second formant prominence and discontinuities in F2 trajectories near SubF2 consistently occur in back-front diphthongs, in accordance with the acoustic model, while for monophthongs front and back vowel F2 values pattern above and below SubF2, as expected under the quantal hypothesis. An additional analysis of the data is presented, showing that breathiness, attenuation, and discontinuity are positively correlated across back-front diphthongs, as predicted by the acoustic model. Lastly, a cross-linguistic survey of F2 data from 45 languages from the literature is presented, showing the cross-linguistic plausibility of the hypothesis that [+back] and [−back] vowel F2 values are separated by SubF2.

9:20

3aSC4. Development of subglottal quantal effects in young children. Youngsook Jung (Speech Commun. Group, MIT, Cambridge, MA 02139, and Harvard-MIT Div. of Health Sci. and Technol., Cambridge, MA 02139), Steven M. Lulich, and Kenneth N. Stevens (Massachusetts Inst. of Technol., Cambridge, MA 02139)

Quantal articulatory acoustic relations between formants and subglottal resonances have been shown to define several vowel and consonant distinctive features, including the vowel features (back) and (low). In particular, the *F*2 frequency of front vowels is higher than the second subglottal resonance (Sg2) but is lower than Sg2 for back vowels. Likewise for low vowels, *F*1 is higher than Sg1. Measurements of *F*1 and *F*2 for productions of the vowels /a/ and /ae/ were made on a number of occasions for several children in the age range 2.5–3.7 years. Measurements of Sg1 and Sg2 for each child were obtained from the locations of discontinuities in the *F*1 and *F*2 trajectories in diphthongs and in vowel-consonant transitions. At the earlier ages for these children, there was variability in the utterances, and the *F*1 and *F*2 values deviated from the expected relation. At the later age of 3 years and above, considerable agreement with the expected values of *F*1 and *F*2 in relation to the subglottal resonances was obtained. The transition from the expected quantal relation appears to occur in the age range between 2 and 3 years. [Work supported in part by NIH Grant R01-DC00075.]

9:45—10:00 Break

10:00

3aSC5. Quantal relations from the acoustic coupled resonators of sonorant consonants. Carol Espy-Wilson (ECE Dept., Univ. of Maryland, A. V. Williams Bldg., College Park, MD 20742)

In this talk, we discuss the quantal relations that result from the coupled resonators of sonorant consonants. We have developed three dimensional geometries for light and dark /l/'s and for retroflex and bunched /r/'s based on MRI data from several speakers. In addition, we have used a computer vocal tract program (VTAR) to develop simpler models from MRI-derived area functions for /r/'s, nasal consonants, and nasalized vowels. Our vocal tract modeling shows that zeros occur in all of these cases due to side branches. For /l/, the side branches are the result of the palatal constriction with airflow around the sides of the tongue. For /r/, the side branches are due to the large front cavity, sometimes with space under the tongue. For the nasals and nasalized vowels, zeros occur due to the coupling between the oral and nasal cavities and the paranasal sinuses. We will discuss how the frequencies of the zeros vary as a result of changes in articulatory configurations. In addition, for /r/, we will show the quantal relationship in the frequency of *F*3 and the relative lengths of the cavities anterior and posterior to the palatal constriction.

10:25

3aSC6. Language-independent phonetic definitions of distinctive features. G. N. Clements and Rachid Ridouane (Laboratoire de Phontique et Phonologie, Sorbonne-Nouvelle, 19 rue des Bernardins, 75005 Paris, France, clements@idf.ext.jussieu.fr)

In spite of the fundamental role that distinctive features play in phonology and phonetics, current research continues to raise basic questions concerning how features can be defined in terms of measurable language-independent physical properties in the articulatory and acoustic/auditory domains. It has been proposed that for a feature to be recovered from a speech event, not only must its articulatory condition be met but the acoustic definition must be satisfied, in the absence of which further enhancing attributes must be present [K. N. Stevens, "Acoustic and perceptual evidence for universal phonological features," Procedings of the 15th International Conference of Phonetic Sciences, Barcelona, 2003 (unpublished), pp. 33–38]. This paper addresses this proposal through the study of the phonetic feature (spread glottis), drawing upon acoustic, fiberscopic, and photoelectroglottographic data from Berber and Kabiyé. A definition for this feature is proposed which associates a specific articulatory state with an equally specific acoustic definition, holding for the full set of sounds and contexts in which this feature can be implemented.

10:50

3aSC7. Acoustic characteristics of glides /j/ and /w/: Interactions with phonation frequency. Elisabeth Hunt (Speech Commun. Group, RLE, MIT, 77 Massachusetts Ave., Rm. 36-549, Cambridge, MA 02139, ehon@speech.mit.edu)

As part of a larger study of acoustic characteristics of glides, patterns in the movements of the fundamental frequency of phonation (*F*0) were measured during utterances of the glide segments /j/ and /w/. Two male and two female American English speakers produced intervocalic glides in six different vowel contexts and five different prosodic contexts. *F*0 contours show pronounced valleys during glide segments, in which the frequency of phonation is decreased relative to the surrounding prosodic contour. These valleys occur more frequently for higher fundamental frequencies, as in female speech. Effects of surrounding vowel and prosodic contexts were also observed, with *F*0 valleys more often occurring during glides when the following vowel is pitch accented or when the height of the surrounding vowels is high. The results are interpreted in terms of acoustic loading on the glottal source; the effects of which are most pronounced when a narrow vocal tract constriction (as in a glide segment) lowers the first formant frequency into the range of *F*0. This interaction with *F*0 may provide an enhancing acoustic cue to the presence of glides in the speech stream, particularly for female speakers or high-vowel contexts. [Work supported in part by NIH Grant No. DC00075.]

11:15

3aSC8. F0 control in electrolarynx speech. Yoko Saikachi (Speech and Hearing Bioscience and Technol., Harvard-MIT Div. of Health Sci. and Technol., Cambridge, MA 02139, yokos@mit.edu), Kenneth Stevens (MIT, Cambridge, MA 02139), and Robert Hillman (Massachusetts General Hospital, Harvard Med. School, Boston, MA 02114)

Over half of laryngectomy patients use an electrolarynx (EL) to communicate, but current EL devices produce a mechanical sound quality mainly due to the lack of natural *F*0 variation. In order to improve the sound quality of EL speech, the present study aimed to develop and evaluate an automatic *F*0 control scheme, where *F*0 in EL speech is covaried based on modulations in the rms amplitude

of the EL speech signal. Declarative sentences ending with vowels produced by two male laryngectomy patients before and after the laryngectomy were used in order to develop procedures for controlling $F0$. The linear regression coefficients between $F0$ and rms amplitude in the normal speech were first determined and applied to the amplitude variation in EL speech to compute the $F0$ contour for the EL sentences. An analysis-by-synthesis approach was employed to modify the $F0$ contour of the EL speech as computed. Perceptual evaluation showed that the addition of amplitude-based $F0$ modulation resulted in EL speech that was judged to be more natural sounding than EL speech having constant $F0$, supporting the idea of using a simple linear relationship between amplitude and frequency to compute an $F0$ contour. [Work supported by NIH Grant No. R01DC006449.]

WEDNESDAY MORNING, 12 NOVEMBER 2008 LEGENDS 12, 8:55 TO 11:25 A.M.

Session 3aSP

Signal Processing in Acoustics, Underwater Acoustics, and Engineering Acoustics: Autonomous System Acoustic Sensors and Processors

Juan Arvelo, Chair
Johns Hopkins Univ., Applied Physical Lab., 11100 Johns Hopkins Rd., Laurel, MD 20723-6099

Chair's Introduction—8:55

Invited Papers

9:00

3aSP1. Advanced classification techniques for real-time signals in resource-constrained systems. G. Scott Peacock, David Barsic, and Ashley Llorens (Johns Hopkins Appl. Phys. Lab, 11100 Johns Hopkins Rd., Laurel, MD 20723-6099)

Automated classification of situational awareness data collected by autonomous vehicles is currently an unmet need in many applications. Classification algorithms developed at JHU/APL extend large margin classification (LMC) machine learning techniques to solve domain-specific problems such as those found in unmanned undersea vehicles systems. Common classification issues for the described systems include the following: (1) Asymmetric binary class membership, that is, a small amount of a target signal must be distinguished in a very large collection of data; (2) no silver-bullet features, i.e., robust classification requires many weak features, are used to distinguish targets from other signals; and (3) limited processing resources. The JHU/APL solution uses existing LMC technology with modifications to solve specific domain issues: (1) addition of a penalty term to address class asymmetry, (2) an iterative training algorithm that yields a sparse solution optimized for a given computational footprint, and (3) featureless classification that requires minimal or no data reduction and can improve classification robustness of the algorithm and cut development costs. Use of these developed techniques is demonstrated using well studied open source data that are representative of that required for autonomous vehicle classification tasks.

9:20

3aSP2. Time-frequency variations of the bistatic scattering response of proud and buried elastic shells in shallow water: Implication for mine counter-measure sonar systems. Shaun D. Anderson, Karim G. Sabra (Woodruff School of Mech. Eng., Georgia Inst. of Technol., 771 Ferst Dr. NW, Atlanta, GA 30332-0405), Manell E. Zakharia (French Naval Acad., BP600, 29240 Brest armees, France), William A. Kuperman (Univ. of California, San Diego, La Jolla, CA 92093-0238), and Henrik Schmidt (MIT, Cambridge, MA 02139)

For underwater sonar, time-frequency analysis has been shown to be a relevant tool for the detection and classification of man-made targets (shell). For instance, for traditional monostatic systems, a key energetic feature of spherical shell is the coincidence pattern, or midfrequency enhancement, that is created by the coherent addition of antisymmetric Lamb-waves propagating clockwise and counterclockwise around the shell. The development by the Navy of mine countermeasure sonar systems, using a network of autonomous systems in unmanned vehicles, provides a mean for bistatic measurements, and thus potentially bistatic enhancement for target detection. We have investigated the time-frequency variations of the bistatic scattering response of elastic shells. The influence of the medium parameters as well as the source-receiver configuration will be investigated in free space and then extended to the case of a shallow water waveguide. In particular, we studied the bistatic variations of the coincidence pattern for classification purposes. Finally, the design of a robust space-time-frequency bistatic sonar system will be discussed to enhance the target detection of shells with the use of multiple sensors.

9:40

3aSP3. Signal processing strategies for autonomous underwater acoustic systems. Paul Hursky, Martin Siderius, Michael B. Porter (3366 North Torrey Pines Court, Ste. 310, La Jolla, CA 92037), Vincent K. McDonald, John M. Stevenson, and Brian Granger (SPAWAR Systems Ctr., San Diego, CA 92152)

Designing autonomous systems for underwater acoustic applications presents a number of competing challenges—these systems must adapt to a wide variety of possible events without human intervention, and they must do so without using much power. To address these challenges, we have explored algorithms borrowed from software-defined radio, octave processing (aka proportional processing),

parametric approaches (that do not require continuous sampling), and algorithms amenable to parallelism. Important functions for realizing autonomy include reducing the dimensionality of the data in stages, associating observations within and across platforms, maintaining multiple hypotheses, and opportunistic specialized processing to resolve outstanding ambiguities. We will describe our resulting embedded processing system and how we adapt this system to two related applications: environmental mapping and marine mammal observation. We will address the following questions: Does mobility help? Do greater numbers of less capable platforms help redress loss of individual platform capability? How much communications bandwidth do we need? We will close by presenting processing results produced by this system during several experiments at sea.

10:00—10:15 Break

10:15

3aSP4. Aggressive adaptive beamforming for ambient noise inversion with a limited-aperture sonar on an autonomous platform. Juan Arvelo, Jr. (The Johns Hopkins Univ. Appl. Phys. Lab., 11100 Johns Hopkins Rd., Laurel, MD 20723-6099)

Bottom loss inference from ambient noise inversion has been shown to yield accurate and robust predictions of undersea sound propagation and sonar detection performance using vertical line arrays and a conventional beamformer [J. I. Arvelo, J. Acoust. Soc. Am. **123**, 679 (2008)]. However, any array with a vertical aperture should be good candidates for ambient noise inversion. The main problem with vertical line arrays is that they are not well suited to rapidly survey a large area. Platform translation with a vertical array is expected to cause extreme array shape distortions that could seriously limit the accuracy of the results. To mitigate array shape distortion, a smaller array with vertical aperture could be mounted on the survey platform, which would allow it to survey the area at greater speeds. The platforms' diameter certainly limits the vertical aperture of the array. A limited vertical aperture limits the frequency range, resolution, and accuracy of the estimated bottom loss. Since the array is rigidly fixed to the platform's body, an aggressive adaptive beamformer may be adopted to increase the resolution and accuracy of the inverted bottom loss to very low frequencies. The performance is demonstrated via comparisons against conventional beamformers with numerical simulations and measurements.

10:35

3aSP5. Geoacoustic inversion of ocean surface-wave noise with a littoral glider. Billy D. Jones (Alaska Native Technologies, LLC, 26273 Twelve Trees Ln., Ste. M, Poulsbo, WA 98370, billy@alaskanativetech.com)

Passive acoustics can be used to characterize the ocean bottom in a littoral environment. Ocean surface-wave noise acts as a natural directional source that can be measured to obtain bottom loss and subsequently inverted to obtain bottom density, sound speed, attenuation, and layering structure. A physical ocean surface noise model is introduced and its horizontal/vertical spatial cross-correlations is discussed. Acoustical energy conservation and its relation to bottom loss are discussed. The measurement method is a continuation of the ambient noise inversion work of [J. I. Arvelo, Jr., J. Acoust. Soc. Am. **123**, 679–686 (2008)]. Aggressive adaptive beamforming is used for high-resolution bottom loss measurements with surface-wave noise as a source. Ambient noise measurements with an eight-element wire polyvinylidene fluoride vertical line array mounted in the bow of a littoral glider are presented. Results from summer 2008 measurements in Port Madison, WA are presented and compared against known bottom loss curves for the area. [Work supported by SPAWAR.]

3a WED. AM

Contributed Papers

10:55

3aSP6. Using the holographic property of synthetic aperture sonar images to enable real aperture sonar navigation. Richard Rikoski and Jose Fernandez (Naval Surface Warfare Ctr., Panama City, Panama City, FL 32407)

Synthetic aperture sonar (SAS) images contain broadband multiaspect information about a scene; this leads to several holographic properties. The most commonly understood property is that a complete image can be reconstructed at lower resolution from any subband of the Fourier transform; this effect is used for speckle reduction. A less commonly understood property is that a SAS image contains all possible real aperture images over some range of angles and frequencies. This allows real aperture images to be coherently correlated with SAS images. The ability to coherently correlate sonar images permits the use of a broad class of probabilistic feature-based navigation algorithms. This paper describes the method of coherently correlating SAS and real aperture images for navigation, and presents results from St. Andrew Bay and the Gulf of Mexico using the small synthetic aperture minehunter.

11:10

3aSP7. Geometrical distortion correction in attitude estimating Hough transformation. Hisashi Shiba (Radio Application Div., NEC Corp., 1-10, Nisshin-cho, Fuchu, Tokyo 183-8501, Japan, h-shiba@aj.jp.nec.com)

In the previous meeting, a new underwater vehicle attitude estimation procedure was presented. It is based on a three dimensional expansion of the Hough transformation detecting the sea surface. It is robust for noise and does not require *a priori* knowledge whether the sea surface and/or the seafloor are in the obtained sonar image. After a rough investigation, it was found that two types of geometrical distortions sometimes affect the Hough transformation results. The distortions are intrinsic in the Hough transformation. One of them is caused by nonlinear relationship between the real space and the parameter space. Another originates from digital geometrical measurements. The former is able to be suppressed by the inverse Hough transformation. The latter is resolved by applying a Euclidean distance area measurement. The two methods are explained in detail in this presentation. These problems tend to be distinguished especially in severe noise environments and it is possible to emerge in usual line detections on two dimensional images. After explaining the two methods, the Hough transformation effectiveness for a real data is also shown by tank experiment results.

Session 3aUW

Underwater Acoustics and Signal Processing in Acoustics: Robust Array Processing

Claire Debever, Chair
Scripps Inst. of Oceanography, Marine Physical Lab., 8820 Shellback Way, La Jolla, CA 92093-0238

Chair's Introduction—8:30

Invited Papers

8:35

3aUW1. Spatial coherence? Henry Cox (Lockheed Martin, 4350 N. Fairfax Dr., Ste. 470, Arlington, VA 22203, harry.cox@lmco.com)

The term spatial coherence is frequently used to summarize the impact of the propagation environment on array performance and to suggest a limitation on useful array aperture. A source of considerable confusion is that there is no single widely accepted precise meaning of the term. In general, coherence implies a fixed phase relationship and involves time as well as space. The time duration over which the measurement is made or for which the phase relationship appears fixed is central to the measurements of coherence. A number of different measurements types and associated data analyses are described and the results are interpreted in terms of the pertinent aspects of acoustic propagation, such as multipath, surface and internal waves, etc. The effects of source and receiver motion are also considered. The implications for array performance and the robustness of beamforming approaches in the face of environmental variability and uncertainty are also discussed. Examples are given from recent shallow water experiments. [Work supported in part by NAVSEA Contract No. N00024-07-C-5210.]

8:55

3aUW2. Image-based refocusing of ultrasound arrays in the presence of strongly scattering objects. John Ballard and Emad Ebbini (Dept. Elec. and Comput. Eng., Univ. of Minnesota, 200 Union St. SE, Minneapolis, MN 55455, ball0250@umn.edu)

Ultrasound phased arrays are currently being investigated for a dual-mode (imaging/therapy) operation in targeting deep-seated abdominal tumors for selective destruction noninvasively. In some cases, e.g., liver tumors, the target is partially obstructed by the ribcage, which limits the array gain at the target. In addition, the intensity at the ribs may be high enough to cause treatment-limiting pain and/or collateral damage to the tissues surrounding the ribs in the path of the therapeutic beam. Using the imaging capabilities of these dual-mode arrays, we have formulated and experimentally verified a robust minimum variance beamforming algorithm for adaptive refocusing in the presence of the ribs. The algorithm utilizes image data of the treatment region formed using conventional beamforming in estimating the array steering vector at the target and the weighting matrix that maximizes the array gain at the target. In this paper, we will describe the mathematical formulation and present experimental data to demonstrate its robustness. We will also discuss the implications of the method, the use of ultrasound phased arrays for imaging, and therapy of trans-thoracic targets such as the liver and the heart.

9:15

3aUW3. Bayesian localization and tracking with environmental and array-element uncertainties. Stan Dosso (School of Earth and Ocean Sci., Univ. of Victoria, Victoria, BC V8W 3P6, Canada, sdosso@uvic.ca), Dag Tollefsen (Norwegian Defence Res. Establishment, 3191 Horten, Norway), and Michael Wilmut (Univ. of Victoria, Victoria, BC V8W 3P6, Canada)

This paper considers matched-field source localization and tracking when environmental parameters and/or array-element positions are not well known. A Bayesian formulation is applied in which source, array, and environmental parameters are considered unknown random variables constrained by noisy acoustic data and by prior information on parameter values (e.g., physical limits for environmental properties and element positions) and on interparameter relationships (e.g., limits on source speed and interelement spacing). The goal then is to extract source information from the posterior probability density (PPD). One approach is based on maximizing the PPD over all parameters to obtain optimal source locations. A key to solving this problem efficiently is that the VITERBI algorithm is applied to compute the highest-probability source track for each environment/array realization: this provides the optimal track, while requiring the optimization is applied only over the nuisance parameters. A second approach involves integrating the PPD over unknown environmental and array parameters to represent source-location information as a series of joint marginal probability surfaces over range and depth. Given the strong nonlinearity of this problem, marginal PPDs are computed numerically using efficient Markov-chain Monte Carlo importance sampling methods. The approaches are illustrated with examples based on simulated and measured acoustic data.

9:35

3aUW4. Robust adaptive beamforming: Evolution of approaches, analysis, and comparison. Sergiy A. Vorobyov (Dept. of ECE, Univ. of Alberta, 9107-116 St., Edmonton, AB T6G 2V4, Canada)

A so-called worst-case-based robust adaptive beamforming approach has been proposed a few years ago. This approach has been followed up by a number of works, which significantly improved the implementation issues. Recently, two new approaches have been developed: the probability constrained based and sequential quadratic programing based approaches. The probability constraint based

design requires the distortionless response constraint to be kept with a certain selected probability, while the worst-case-based design requires this constraint to be kept for the worst-case operational conditions. The sequential quadratic programing based approach uses the iterative estimation of the signal steering vector and, therefore, is significantly different from two two aforementioned designs. In this paper, we overview, analyze, and compare all the aforementioned approaches to robust adaptive beamforming design.

9:55

3aUW5. Robust processing techniques for underwater acoustics. Lisa Zurk (ECE Dept., Portland State Univ., P.O. Box 751, Portland, OR 97207, zurkl@pdx.edu)

The performance of sonar signal processing methods in shallow water waveguides is highly sensitive to the effects of the acoustic wave propagation, and the nature of this propagation is often critically dependent on the exact nature of the underwater channel. Signal processing formulations that exploit the structure of the channel have been shown to increase detection and localization performance when the channel properties are known. However, for many tactical situations, channel parameters are poorly unknown or "uncertain," thus motivating the need for robust processing techniques that do not require exquisite knowledge of the environment but may still exhibit the increased performance of full field methods. The goal of devising robust processing approaches remains of high interest and is an ongoing topic for signal processing research. This presentation first provides some metrics of environmental uncertainty and the effect on the sonar signal processing then provides a review of several proposed approaches for achieving robustness. The algorithms are grouped into the following three categories: robust matched field processing algorithms, guide source calibration techniques, and invariance processing (both passive and active). The presentation concludes with a discussion of ongoing research and future areas for investigation.

10:15—10:30 Break

Contributed Papers

10:30

3aUW6. Broadband high frequency matched-field processing. Claire Debever and William A. Kuperman (Scripps Inst. of Oceanogr., UCSD, 9500 Gilman Dr., Mail Code 0238, La Jolla, CA 92093-0238, cdebever@ucsd.edu)

Adaptive matched-field processing (MFP) is extremely sensitive to environmental uncertainties. While conventional and adaptive techniques may work for low-frequency signals in well-studied environments, the localization performance usually degrades rapidly as frequency increases, such that MFP in the 3.5 kHz regime, in shallow water environments, is typically problematic. A broadband coherent method [IEEE J. Ocean. Eng. **21**, 384–392], combined with white noise constraint and principal component techniques, is implemented to construct robust replicas from experimental data. Matched-field tomography is then used to better understand the origin of the frequency dependent MFP mismatch (uncertain bottom structure, sound speed fluctuations, or both), and the results are compared with simulations. Ultimately, we want to gain some insights into how to implement a robust matched-field processor for high-frequency scenarios without using experimental data to create replica vectors. In particular, we are seeking to understand the thresholds for adaptive processors as function of signal to noise ratio and frequency dependent environmental mismatch. [Work supported by ONR.]

10:45

3aUW7. Geoacoustic tracking. Caglar Yardim, Peter Gerstoft, and William Hodgkiss (Marine Physical Lab., Scripps Inst. of Oceanogr.-0238 9500 Gilman Dr., La Jolla, CA 92093-0238)

This paper shows how to incorporate tracking techniques such as the extended Kalman, unscented Kalman, and particle filters into geoacoustic inversion problems. This enables not only the inversion of environmental parameters but also the spatial and temporal tracking of them, making geoacoustic tracking a natural extension to geoacoustic inversion techniques. Water column and seabed properties are tracked in simulation and using the MAPEX2000 experimental data for both vertical and horizontal line arrays. Filter performances are compared in terms of filter efficiencies using the posterior Cramér–Rao lower bound. Tracking capabilities of the geoacoustic filters under slowly and quickly changing environments are studied in terms of divergence statistics. The suitability of each filter in geoacoustic tracking is discussed in terms of the track quality, complexity of the probability density function of environmental parameters, nonlinearity of the geoacoustic propagation, and computational cost. The results show that geoacoustic tracking can provide continuously environmental estimates and their uncertainties using only a fraction of the computational power of classical geoacoustic inversion schemes. [Work supported by ONR-N00014-05-1-0264.]

11:00

3aUW8. Inversion of ocean environmental variations via time reversal acoustics. Wen Xu and Jianlong Li (Zheda Rd. 38, Dept. of Information Sci. and Electron. Eng., Zhejiang Univ., Hangzhou 310027, China)

Time reversal (TR) processing is derived from the invariance of the wave equation for lossless medium to change in the sign of the time variable. By retransmitting the TR version of the time-dispersed received signal propagated from a probe source (PS) to a source-receiver array, one can reacquire the transmitted pulse at the PS location (time compression and spatial focusing) when the waveguide environment is time invariant. However, if some environmental variations occur between the two transmissions, the retrofocusing signal will be defocused. This paper presents a new method of environmental parameter inversion by comparing the difference of the focused signals measured at the PS location with/without environmental perturbations. Because the sound speed profile (SSP) plays a critical role in an uncertainty ocean environment, inversion of the SSP represented in terms of the empirical orthogonal functions is developed and discussed in detail. Simulations demonstrate some advantages of environmental inversion via TR: (1) great signal-to-noise ratios can be obtained at the PS location; (2) variations of the environment at different times can be directly inverted by repeatedly retransmitting either the same received signal generated by one PS transmission or the updated received signals generated by updated PS transmissions.

11:15

3aUW9. Arrival time estimation from sound signals in the ocean: A particle filtering approach. Rashi Jain and Zoi-Heleni Michalopoulou (Dept. of Mathematical Sci., New Jersey Inst. of Technol., Newark, NJ 07102, rj45@njit.edu)

The focus of this work is on accurate arrival time estimation from measured time-series at an array of vertically separated hydrophones in the ocean. We develop a particle filtering approach that treats arrival times as "targets", dynamically modeling their "location" at arrays of spatially separated receivers. Using Monte Carlo simulations, we perform an evaluation of our method and compare it to conventional maximum likelihood estimation, whereas we also compare our errors to Cramer–Rao bounds. The comparison demonstrates an advantage in using the proposed approach, which can be employed for minimization of uncertainty in arrival time estimation. Improved arrival time estimates can then be used for accurate geoacoustic inversion and source localization. [Work supported by ONR.]

Meeting of Accredited Standards Committee (ASC) S3 Bioacoustics

C. A. Champlin, Chair S3
University of Texas, Department of Communication Sciences & Disorders, CMA 2-200, Austin, TX 78712

D. A. Preves, Vice Chair S3
Starkey Laboratories, Inc., 6600 Washington Ave., S., Eden Prairie, MN 55344

Accredited Standards Committee S3 on Bioacoustics. Working group chairs will report on the status of standards under development. Consideration will be given to new standards that might be needed over the next few years. Open discussion of committee reports is encouraged.

People interested in attending the meeting of the TAGs for ISO/TC 43 Acoustics and IEC/TC 29 Electroacoustics, take note - those meetings will be held in conjunction with the Standards Plenary meeting at 9:15 a.m. on Tuesday, 11 November 2008.

Scope of S3: Standards, specifications, methods of measurement and test, and terminology in the fields of psychological and physiological acoustics, including aspects of general acoustics which pertain to biological safety, tolerance and comfort.

WEDNESDAY MORNING, 12 NOVEMBER 2008 CARISSA ROOM, 10:45 A.M. TO 12:00 NOON

Meeting of Accredited Standards Committee (ASC) S3/SC 1, Animal Bioacoustics

D. K. Delaney, Chair S3
USA CERL, 2902 Farber Drive, Champaign, IL 61822

W. Au, Vice Chair S3
Hawaii Institute of Marine Biology, P. O. Box 1106, Kailua, HI 96734

Accredited Standards Committe S3/SC 1 on Animal Bioacoustics. Working group chairs will report on the status of standards under development. Consideration will be given to new standards that might be needed over the next few years. Open discussion of committee reports is encouraged.

Scope of S3/SC 1: Standards, specifications, methods of measurement and test, and terminology in the field of psychological and physiological acoustics, including aspects of general acoustics, which pertain to biological safety, tolerance and comfort of non-human animals, including both risk to individual animals and to the long-term viability of populations. Animals to be covered may potentially include commercially grown food animals; animals harvested for food in the wild; pets; laboratory animals; exotic species in zoos, oceanaria or aquariums; or free-ranging wild animals.

Session 3pAA

Architectural Acoustics: The Technical Committee on Architectural Acoustics Vern O. Knudsen Distinguished Lecture

David Lubman, Cochair
DL Acoustics, 14301 Middletown Ln., Westminster, CA 92683-4514

William J. Cavanaugh, Cochair
Cavanaugh Tocci Assoc., Inc., 327F Boston Post Rd., Sudbury, MA 01776-3027

Chair's Introduction—1:00

Invited Paper

1:05

3pAA1. Aural architecture: The missing link. Barry Blesser (Blesser Assoc., P.O. Box 155, Belmont, MA 02478, bblesser@alum.mit.edu)

While acoustic architecture focuses primarily on the acoustic physics of objects and geometries, aural architecture emphasizes the experience of space in terms of behavior and emotions. Because auditory spatial awareness, which is the basis for aural architecture, depends on a social value system, the role of acoustics varies among individuals and cultures. When evaluating the aural experience of space, two independent phenomena must be simultaneously considered: Space changes our experience of sound and sound changes our experience of space. Sound sources and spatial acoustics are inseparable. This bilateralism creates an interdisciplinary complexity that fuses physical and social sciences. Hearing is a means by which people acquire a sense of where they are, connecting them to dynamic events and spatial geometry. Auditory spatial awareness allows people to sense the elegance of a plush office, the emptiness of an uninhabited house, the depth of a dark cave, the quiet of a city covered in snow, the vastness of a railroad station, and the openness of a beach front. Each of these situations can be described in the language of aural architecture, which includes at least five types of experiential spatiality: navigational, social, aesthetic, symbolic, and musical.

2:05—2:15 Question and Answer
2:15—2:45 Book Signing

WEDNESDAY AFTERNOON, 12 NOVEMBER 2008 LEGENDS 3/4, 2:15 P.M. TO 3:15 P.M.

Session 3pED

Education in Acoustics: Acoustics Education Prize Lecture

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

Chair's Introduction—2:15

Invited Paper

2:20

3pED1. From the sublime to the scientific: What musicians and acousticians can learn from each other. Murray Campbell (School of Phys. and Astronomy, Univ. of Edinburgh, Edinburgh EH9 3JZ, UK)

Many university music programs include an acoustics module, often taught by a physicist. At the University of Edinburgh, such a module has existed since the 1850s; taking over this course as a junior lecturer was my introduction to the fascinating world of musical acoustics. It rapidly became clear that a meaningful communication between scientists and musicians required humility and willingness to learn from both sides. This lecture explores aspects of that mutual learning process, focusing on some controversial areas in which the reconciling of scientific and musical viewpoints has not always proceeded in a spirit of humility.

Session 3pID

Interdisciplinary: Hot Topics in Acoustics

David R. Dowling, Chair
Univ. of Michigan, Dept. of Mech. Eng., 1231 Beal Ave., Ann Arbor, MI 48109-2133

Chair's Introduction—1:00

Invited Papers

1:05

3pID1. Hot topics in engineering acoustics. David A. Brown (BTech Acoust. LLC, and Electro-Acoust. Res. Lab., Adv. Tech. Manuf. Ctr. and ECE Dept, Univ. of Massachusetts Dartmouth, 151 Martine St., Fall River, MA 02723)

The maturation of single crystal piezoelectric materials in the past decade has spawned a renewed interest in traditional and new transducer designs for underwater acoustic and medical imaging applications. The engineering of acoustic devices based on piezoelectric crystals began in the first half of the 20th century and was overtaken by developments in ferroelectric ceramic compounds such as barium-titanate and lead-zirconium-titanate (PZT). These materials are now being challenged by engineered relaxor piezoelectric single crystals materials such as lead-magnesium (or zirconium or indium)-niobate-lead-titanate (PMN-PT, PZN-PT, and PIN-PT) in many applications. The new materials have tremendous improvements in piezoelectric properties including electromechanical coupling coefficients exceeding 90%, which can double the power factor bandwidth for underwater projectors, sound speeds that are a factor of 3 lower than PZT that enable compact low frequency sources, and strain levels as high as 1% for high drive and actuator applications. The hot topics related to engineering acoustics involve the development and commercialization of devices based on new and traditional transducer designs that exploit the novel properties of the new crystal materials. Examples of broadband underwater communications transducers, tonpiltz sonar projectors, pressure and pressure-gradient hydrophones, mechanical actuators, and medical devices are presented.

1:25

3pID2. Uncertainty in ocean acoustics. Steven Finette (Acoust. Div. Naval Res. Lab., Washington, DC 20375-5320, steven.finette @nrl.navy.mil)

When modeling ocean-acoustic systems, the environmental information necessary to compute the acoustic field properties is assumed to be accurately specified by various parameters, fields, and boundary conditions. However, in real world applications, these quantities are subject to uncertainties due to our incomplete knowledge of the waveguide environment. This form of uncertainty involves errors that are quite distinct from the numerical errors that can arise when a mathematical model is discretized, implemented on a computer, and solved with finite precision arithmetic. In effect, the environmental uncertainty introduces spurious degrees of freedom into the system. In order to make reliable simulation-based predictions, this uncertainty needs to be quantified and incorporated in the simulation process itself. The idea of embedding uncertainty into the simulation framework and elevating its status to a subject worth studying on its own merits represents a paradigm shift that has stimulated research in several disciplines. This talk will overview recent approaches to this problem in an ocean-acoustic context and give examples of computations that have incorporated environmental uncertainty in the numerical computation of acoustic field properties. [Work supported by the Office of Naval Research.]

1:45

3pID3. Hot topics in physical acoustics. Joseph Gladden, III (Dept. of Phys., Univ. of Mississippi, University, MS 38677, jgladden @phy.olemiss.edu)

The field of physical acoustics touches a broad range of technical areas important to fundamental science and society. This "Hot Topics" presentation will reflect the breadth of this impact by discussing the following three topics: sound waves in the early cosmos, acoustics in slip-stick friction systems, and acoustic metamaterials. The early universe, composed of hot ionized matter, was able to support acoustic waves until the temperature cooled enough to allow the formation of neutral atoms. The imprint of these relic acoustic waves is still evident in the cosmic microwave background and yields new information about key cosmological constants and dark matter. Earthquakes are perhaps the most destructive of natural disasters, as was painfully demonstrated by recent events in China. Studies on the effects of acoustic vibrations in slip-stick friction systems have begun to shed light on triggering mechanisms for earthquakes and may lead to better early warning systems. Metamaterials are man-made materials in which precise geometric arrays of structures are engineered to produce coherent scattering effects on scales much larger than the structures themselves. These systems can exhibit such exotic properties as a negative index of refraction, band gaps, and a negative effective elastic modulus.

Session 3pSC

Speech Communication: A Quantal Transition: Ken Stevens in "Retirement" II

Helen M. Hanseon, Chair
Union College, Electrical and Computer Eng. Dept., 807 Union St., Schenectady, NY 12308

Invited Papers

1:00

3pSC1. Enhancing the left edge: The phonetics of prestopped sonorants in Australian languages. Andrew Butcher (School of Medicine, Flinders Univ., GPO Box 2100, Adelaide SA 5001, Australia, andy.butcher@flinders.edu.au) and Debbie Loakes (Univ. of Melbourne, Parkville, VIC 3010, Australia)

The consonant systems of Australian Aboriginal languages are very similar to one another but very different from those of most other languages of the world. They have unusually few contrasts in manner of articulation and an unusually large number of places of articulation. Previous research has shown that speakers appear to employ a number of strategies to preserve place of articulation distinctions, particularly in intervocalic (coda) consonants. One such strategy is that in vowel + nasal sequences speakers avoid lowering the velum until the latest possible instant, presumably to preserve spectral clarity at the VC boundary. This often results in a brief homorganic oral stop occurring before the nasal. Phonetically prestopped nasals occur in a large number of languages across Australia and have become distinctive phonemes in a number of languages in the center and south. Less well documented is the parallel phenomenon of prestopped laterals, which is taken to be the outcome of a similar coarticulation avoidance strategy. This paper describes the wide distribution and distinctive phonetic characteristics of prestopped nasals and laterals in a number of Australian languages and proposes that both strategies are aimed at the enhancement of the left edge of the sonorant consonant.

1:25

3pSC2. Quantal events generated by the structural and temporal variation of the vocal tract. Brad Story (Dept. of Speech, Lang., and Hearing Sci., Univ. of Arizona, P.O. Box 210071, Tucson, AZ 85721)

For connected speech, the time-varying vocal tract shape can be represented as a consonant superposition function that imposes constrictions and expansions on an underlying vowel substrate at specific points in space and time. The resulting flow of continuous speech sounds is a combination of characteristics of both the vowels and the consonants. A question is how speakers choose specific spatial locations and temporal patterns with which to execute particular consonants. In this study, acoustic sensitivity functions and formant nomograms based on a vocal tract area function model were used to determine the optimal locations for consonantal constrictions. Specifically, these techniques indicate the points within the vocal tract at which the acoustic effect of a constriction, in terms of formant frequency transitions, will rapidly change. These points are suggestive of quantal events that may occur during production of speech. [Work supported by NIH R01-DC04789.]

1:50

3pSC3. Consonant landmarks: Automatic detection and interpretation. Chiyoun Park and Nancy Chen (MIT, 77 Massachusetts Ave., Rm. 36-525, Cambridge, MA 02139)

Consonant landmarks are acoustic discontinuities in the speech signal that correspond to the closures and releases in speech production, and have been proposed as critical elements in speech processing [Stevens (2002)]. The three types of consonant landmarks represent the onset and offset of salient acoustic events: glottal vibration, turbulence noise, and sonorancy (e.g., nonvocalic voicing). While earlier work [Liu, (1996)] evaluated the success of identifying single candidate landmarks of all three types, this work focuses on two tools for evaluating strings of landmark candidates. First, a bigram model representing the physiologically feasible sequences of consonant landmarks is used to evaluate candidate strings. Second, a graphical method is used to identify the regions where the landmarks are reliably detected versus where they are ambiguous. Together these tools substantially improve the performance for landmark detection, identify regions in need of further acoustic analysis, and model the 'grammatical' structure of landmark sequences. Furthermore, the reliable regions in the proposed representation often correspond to structural elements such as lexical stress and word boundaries. Thus, the proposed representation is potentially useful in analyzing speech not only at the phoneme level but also at the word and phrase levels. [This work was supported by NIH/NIDCD DC02978 and T32DC00038.]

2:15

3pSC4. Point process models of distinctive feature landmarks for speech recognition. Aren Jansen and Partha Niyogi (Dept. of Comput. Sci., Univ. of Chicago, 1100 E 58th St., Chicago, IL 60637, aren@cs.uchicago.edu)

Several interrelated strands of research in linguistics, acoustic phonetics, and cognitive neuroscience suggest a host of new directions for the development of end-to-end computational models of speech perception and recognition. Natural candidates for exploration include (i) phonological representations in terms of distinctive features; (ii) nonlinear detectors for distinctive feature landmarks (or any other set of perceptually salient acoustic events), which define a sparse point process representation of the speech signal; (iii) syllable-metered temporal processing and/or syllable-sized integration windows; and (iv) point process models and hierarchical strategies for

recognizing words, syllables, phonemes, and features. A computational framework around these ideas has been developed and has led to phonetic recognition and keyword spotting performance that is competitive with equivalent hidden Markov model-based systems. This framework thus connects a computational platform for benchmarking competing scientific theories with simultaneous advancement toward a viable technological solution to the speech recognition problem.

2:40—2:50 Panel Discussion

WEDNESDAY AFTERNOON, 12 NOVEMBER 2008 GRAND BALLROOM A/B, 3:30 TO 5:30 P.M.

Plenary Session and Awards Ceremony

Mark F. Hamilton, Chair
President, Acoustical Society of America

Business Meeting of the Acoustical Society of America

Motion to approve the Plan of Merger of the Acoustical Society Foundation, Inc. into the Acoustical Society of America, Incorporated

Presentation of Certificates to New Fellows

DAVID A. BERRY
GEORGE A. BISSINGER
JOHN A. FAWCETT
DENNIS M. FREEMAN
BRUCE R. GERRATT
FRANK H. GUENTHER
KEITH R. KLUENDER
YIU W. LAM
MARSHALL LONG
CHRISTIAN LORENZI
BRYAN E. PFINGST
JOE W. POSEY
STUART ROSEN
ARMEN SARVAZYAN
MICHAEL A. STONE
ANN K. SYRDAL
JOE WOLFE

PRESENTATION OF SCIENCE WRITING AWARDS

SCIENCE WRITING IN ACOUSTICS FOR A JOURNALIST

HAZEL MUIR FOR "NOISY NEIGHBOURS" PUBLISHED IN *NEW SCIENTIST MAGAZINE*, AUGUST 2007

SCIENCE WRITING AWARD FOR MEDIA OTHER THAN ARTICLES

KATHLEEN VIGNESS RAPOSA, GAIL SCOWCROFT, CHRISTOPHER KNOWLTON, PETER WORCESTER FOR "DISCOVERY OF SOUND IN THE SEA" WEBSITE

PRESENTATION OF ACOUSTICAL SOCIETY AWARDS

ROSSING PRIZE IN ACOUSTICS EDUCATION TO D. MURRAY CAMPBELL

SILVER MEDAL IN MUSICAL ACOUSTICS TO GABRIEL WEINREICH

SILVER MEDAL IN PHYSICAL ACOUSTICS TO PETER J. WESTERVELT

SILVER MEDAL IN SPEECH COMMUNICATION TO WINIFRED STRANGE

WALLACE CLEMENT SABINE MEDAL TO JOHN S. BRADLEY