Session 3pAAa

Architectural Acoustics and Musical Acoustics: Variable Acoustics on Concert Stages II

Bill Dohn, Cochair
Dohn and Associates, Inc., 630 Quintana Rd., Morro Bay, CA 93442

Michelle C. Vigeant, Cochair
Mechanical Engineering, Univ. of Hartford, 200 Bloomfield Ave., West Hartford, CT 06117-1599

Invited Paper

1:00

3pAAa1. Changes in on-stage and in-house listening conditions with adjustments to over-stage canopy height and tilt: Field investigations in two concert halls. Bill Dohn (Dohn and Assoc., Inc., 630 Quintana Rd., #312, Morro Bay, CA 93442, bill.dohn@dohnandassociates.com)

On-stage and in-house measurements were made in two concert halls with adjustable over-stage canopies to assist with future designs and verify recommended canopy settings for facility users. Results of measurements with varying canopy heights and tilt angles will be shared, along with descriptions of the two (very different) canopy designs and the two (very similar) concert hall designs. User preferences for canopy settings in both halls will also be discussed.

Contributed Papers

1:20

3pAAa2. Working with student musicians on developing standard settings for concert stages with adjustable acoustics. David W. Kahn (Acoust. Dimensions, 145 Huguenot St., Ste. 406, New Rochelle, NY 10801)

The acoustician's work on concert stages with adjustable acoustics usually includes a so called "tuning" process. This tuning process is unique and different for students attending music school as compared with, for example, a professional orchestra. We describe a tuning process, working with student musicians, at a new concert hall in Texas. Adjustable elements include movable ceiling elements, movable doors on the upper wall surfaces surrounding the concert platform, and retractable curtains that cover both the upper and lower wall surfaces surrounding the platform.

1:35

3pAAa3. Altering stage acoustics using time variant electro-acoustic enhancement. Steve Barbar (30 Dunbarton Rd., Belmont, MA 02478, steve@lares-lexicon.com)

Time variant electro-acoustic enhancement systems have been successfully installed in a variety of venues and applications since 1990. Many of these systems have included electro-acoustic support for performers on stage, as well as increased direct sound from virtual reflectors, in both indoor and outdoor venues. Examples of these systems and venues are described, including: The Mormon Tabernacle Choir, Vienna Philharmonic Orchestra, and Arnold Schoenberg Choir, Grant Park Symphony, Adelaide Symphony Orchestra, Midland Symphony Orchestra, and Stonebriar Community Church.

1:50

3pAAa4. Variable acoustics systems and their impact on concert platforms. Todd L. Brooks, Clemeth L. Abercrombie, Nathan A. Pape, Damian J. Doria, and Tateo Nakajima (Artec Consultants Inc., 114 W. 26th St. 10th Fl., New York, NY 10001, tlb@artecconsultants.com)

The modern purpose-built concert hall must accommodate an extremely wide range of program, ranging from unamplified solo and chamber music to large-scale symphony and amplified events. Adjustable systems designed for both acoustical and functional flexibility are essential to adapt the stage platform environment to the needs of these different performance types. The successful modern concert hall may include adjustable overhead canopies, adjustable absorption systems, orchestra riser platforms (possibly mechanized), chorus riser wagons, and platform extension/reduction lifts. We will share our experiences and some lessons learned in a variety of recently completed and in-construction projects. Audible differences resulting from differences in architectural contexts will be discussed. We will link possible correlations between aural variations and objective measures with subjective attributes important to the performers.

2:05

3pAAa5. Choir hearing responses: Rehearsal versus performance configurations. Glenn E. Sweitzer (Sweitzer LLP, 4504 N Hereford Dr. Muncie, IN 47304, glenn.sweitzer@gmail.com)

Choir responses to hearing (parts) in a rehearsal room are compared with those for its associated performance stage. Anonymous responses from each choir member are gathered via a hand-held battery-operated device that enables scaled responses (5). The protocol is administered in the rehearsal room for the choir configured by part versus mixed, in straight rows versus curved rows, standing on a flat floor versus risers, and facing a diffusing wall versus an adjustable absorptive wall. This protocol is repeated on the performance stage, except that the choir faces the audience only. Preliminary results suggest that responses vary widely by configuration and suggest that choir response has been largely ignored in the design of and operation of choir rehearsal and performance facilities.

2:20

3pAAa6. Feasibility of converting a conference hall to a music performance hall. L. Y. Cheung (Dept. of Bldg. Services Eng., The Hong Kong Polytechnic Univ., Hung Hom, Kowloon, Hong Kong, China, louisa.cheung@polyu.edu.hk) and S. K. Tang (The Hong Kong Polytechnic Univ., Hong Kong, China, besktang@polyu.edu.hk)

A 3-D-simulation for improving the acoustics in a conference hall was done. This aimed at investigating the possibility of converting it for musical performance. A room modeling software, Odeon, was used to simulate the

effects of adding varies reflectors on the stage with its existing demountable acoustic shell. The following cases were put into simulations: a bare stage, stage with demountable acoustic shell, and stage with acoustic shells with various hanging reflectors above the stage. The additional hanging reflectors with the existing acoustical shell reduce the reverberation time in the hall in most of the cases simulated; however, they increase the average energy levels in the hall. The acoustical shell with the reflector gives a larger energy ratio in average across the octave bands that make the hall more suitable for musical performance. [L. Y. Cheung is supported by the Hong Kong Polytechnic University.]

WEDNESDAY AFTERNOON, 2 NOVEMBER 2011 SUNSET, 1:00 TO 3:00 P.M.

Session 3pAAb

Architectural Acoustics: Workshop for American Institute of Architects Continuing Education Units

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

K. Anthony Hoover, Cochair
McKay Conant Hoover, Inc., 5655 Lindero Canyon Rd., Westlake Village, CA 91362

Invited Papers

1:00

3pAAb1. Technical Committee on Architectural Acoustics short course presentation material. K. Anthony Hoover (McKay Conant Hoover, Inc., 5655 Lindero Canyon Rd., Ste. 325, Westlake Village, CA 91362, thoover@mchinc.com)

The Technical Committee on Architectural Acoustics (TCAA) is a Registered Provider in the American Institute of Architects (AIA) Continuing Education System (CES). The TCAA has developed a standardized introductory short course for architects, called "Architectural Acoustics." An architect can earn one continuing education unit by attending this short course, if it is presented by a qualified member of TCAA. The course covers topics in sound isolation, mechanical system noise control, and finish treatments. This paper will cover the course material in order to prepare and qualify potential presenters. In order to qualify as an authorized presenter for this AIA/CES short course, attendance at this workshop and membership in TCAA are required.

2:00

3pAAb2. American Institute of Architects Continuing Education System Provider Registration and Reporting Requirements. Bennett M. Brooks (Brooks Acoust. Corp., 30 Lafayette Sq., Ste. 103, Vernon, CT 06066, bbrooks@brooksacoustics.com)

The Technical Committee on Architectural Acoustics (TCAA) is a Registered Provider in the American Institute of Architects (AIA) Continuing Education System (CES). The TCAA has developed a standardized introductory short course for architects. The TCAA short course is called "Architectural Acoustics" and attendance at this 1-h long course can earn an architect one continuing education unit with HSW Credit (Health Safety and Welfare). This paper will cover the administrative requirements of the AIA/CES, to prepare potential presenters. These requirements include the proper handling of paperwork, so that AIA members may receive credit for the course. Also, the manner in which the course is given is dictated by AIA requirements. TCAA membership and attendance at this workshop are required to qualify as an authorized presenter for this AIA/CES short course.

Session 3pAB

Animal Bioacoustics: Acoustics for Saving Endangered Species II

Tomonari Akamatsu, Cochair
National Research Inst. of Fisheries Engineering, Hasaki, Kamisu, Ibaraki, 314-0408, Japan

Susan E. Parks, Cochair
Applied Research Lab., Pennsylvania State Univ., P.O. Box 30, State College, PA 16804-0030

Invited Papers

1:15

3pAB1. Exploring the use of acoustics as a tool in male elephant/human conflict mitigation. Caitlin E. O'Connell-Rodwell (Dept. of Otolaryngol., Head & Neck Surgery, Stanford Univ. School of Medicine, 801 Welch Rd., Stanford, CA 94305, ceoconnell@stanford.edu), Rehabeam Erckie (Etosha Natl. Park, Namibia), Werner Kilian (Etosha Ecological Inst., Etosha Natl. Park, Namibia), Jason D. Wood (Univ. of Washington, Seattle, WA, 98195), Colleen Kinzley (Oakland Zoo, Oakland, CA 94605), Timothy C. Rodwell (Univ. of California, San Diego, La Jolla, CA 92093), and Joyce H. Poole (ElephantVoices, Sausalito, CA 94965)

Elephant/human conflict mitigation solutions have been explored with varying degrees of success. We present findings on a potential acoustic tool to reduce negative outcomes of male elephants entering agricultural areas in the region northeast of Etosha National Park, Namibia. We monitored elephant traffic within and outside the park boundary using GPS collars on five male elephants with known hormonal status as well as information on the frequency and location of fence breaks. Male elephants in the hormonal state of musth have an increased range, often extending outside the protected area. We explored the feasibility of attracting musth males away from potential conflict areas noninvasively, using estrus calls. We played back estrus calls to known individual subadult ($n = 9$) and adult musth ($n = 9$) and nonmusth ($n = 6$) male elephants and show that adult musth and subadult nonmusth males were much more likely to respond and approach the source than nonmusth adult males ($p = 0.029$ and $p = 0.009$, respectively) with an equal level of intensity ($p = 0.822$). Our findings suggest that the use of acoustics may serve as an effective tool in noninvasive male elephant/human conflict mitigation, depending on the age and hormonal status.

1:35

3pAB2. Finding baiji and freshwater finless porpoises in the Yangtze River, China. Tomonari Akamatsu (Natl. Res. Inst. of Fisheries Eng., Hasaki, Kamisu, Ibaraki 314-0408, Japan, akamatsu@affrc.go.jp), Lijun Dong, Ding Wang, Kexiong Wang, Songhai Li, Shouyue Dong, Xiujiang Zhao (Chinese Acad. of Sci., Wuhan 430072, P. R.China), and Satoko Kimura (Kyoto Univ., Kyoto 606-8501, Japan)

A stereo passive acoustic event recorder (A-tag) has been applied for range-wide monitoring of baiji and finless porpoises in China. As the pilot study, two research vessels were operated in 1700 km historic habitat of both species from Yichang to Shanghai in 2006. There was no detection of baiji, but 204 and 199 porpoises were counted acoustically by two vessels, respectively. In order to investigate the population trends of cetaceans, periodical survey is necessary. We installed A-tag on the cargo ship, which was operated 1100 km in the river once every month. An average of 6059 clicks and 95 porpoises were acoustically detected in each survey. Detected group sizes of the animals in 120-s time window were not significantly different among the surveys, but the distribution pattern suggested seasonal migration. The animals were detected in most of the survey range except two gap sections with 40 and 60 km lengths, down from Wuhan and Nanjing cities, respectively, where no animals were detected in the first three surveys. Fragmentation of population by anthropological factors was concerned. The cargo ship based passive acoustic survey was effective to monitor the distribution and population trend over time.

1:55

3pAB3. Acoustic monitoring of beluga whales (*Delphinapterus leucas*) in Cook Inlet, Alaska. Manuel Castellote (Natl. Marine Mammal Lab., NOAA Fisheries, Seattle, WA 98115, manuel.castellote@noaa.gov), Robert J. Small (Univ. of Alaska Fairbanks, Juneau, AK), Shannon Atkinson (Univ. of Alaska Fairbanks, Juneau, AK), Marc O. Lammers (Hawaii Inst. of Marine Biology, Kaneohe, HI), Justin jenniges (Univ. of Alaska Fairbanks, Juneau, AK), Anne Rosinski (Hawaii Inst. of Marine Biology, Kaneohe, HI), Chris Garner (U.S. Air Force, Joint Base Elmendorf-Richardson, Anchorage, AK), Sue Moore (NOAA Fisheries, Seattle, WA), and Whitlow W. L. Au (Hawaii Inst. of Marine Biology, Kaneohe, HI)

Cook Inlet belugas (CIB) form a small geographically and genetically isolated population, endangered under the U.S. Endangered Species Act. They summer in the northern end of the inlet, but their wintertime distribution is essentially unknown. Factors impeding the recovery of this population over the last decade are unknown, yet could include anthropogenic activities that impact their acoustic ecology, including coastal development, oil and gas exploration, and shipping and military activities. Beginning in 2008, a cooperative research project has acquired new information on background noise levels and seasonal presence of CIB using passive acoustic monitoring. Mooring packages containing ecological acoustic recorders and echolocation loggers (C-PODs) have been deployed at 10 sites for

continuous monitoring. It is a challenging environment for acoustic monitoring because of extreme tides and currents, sediment dynamics, debris from rivers, and seasonal ice. Noise from both natural and anthropogenic sources often make beluga call detection challenging. However, the effort to date has met with success and is providing valuable insights into beluga movement patterns and the acoustic environment they face. This methodology also allows monitoring other odontocetes such as killer whales (*Orcinus orca*), detected mostly in the lower inlet, and harbor porpoise (*Phocoena phocoena*) detected throughout the inlet.

Contributed Papers

2:15

3pAB4. Distribution pattern of finless porpoises at the junction of the Yangtze River and Poyang Lake observed by towed passive acoustic device. Satoko Kimura (Graduate School of Informatics, Kyoto Univ., 606-8501 Kyoto, Japan, sk0130@bre.soc.i.kyoto-u.ac.jp), Tomonari Akamatsu (Natl. Res. Inst. of Fisheries Eng., Ibaraki 314-0408, Japan), Songhai Li (Chinese Acad. of Sci., Wuhan 430072, China), Lijun Dong, Kexiong Wang, Ding Wang (Chinese Acad. of Sci., Wuhan 430072, China), and Nobuaki Arai (Kyoto Univ., 606-8501 Kyoto, Japan)

The Yangtze finless porpoise (Neophocaena asiaeorientalis asiaeorientalis) is an endangered freshwater porpoise subspecies unique to the Yangtze River basin. Without immediate conservation measures, it could soon become extinct, just as the Yangtze River dolphin (baiji, Lipotes vexillifer). We report seasonal change in the local distribution of the porpoises living in the conjunction area of the middle reaches of the Yangtze River, side streams, and appended Poyang Lake. A towed stereo acoustic data-logger, A-tag, was used to detect echolocation signals and sound source bearing angles. The independent sound source directions provided the number of animals present, not just the number of sounds. Passive acoustic surveys were performed regularly from May 2007 to August 2010. The water level was highest in August (summer) and lowest in February (winter) and at mid-level in May (spring) and November (autumn). The average number of porpoises detected in 11 surveys conducted in different seasons varied from 0.53 to 1.26 individuals per km. No significant trend of reducing number of porpoises was detected during 3-y monitoring. The distribution of the porpoises was seasonally site-specific. In May and August, the animals were detected more often at river junctions than in the lake, but vice versa from November to February.

2:30

3pAB5. Implications of vocalizations during giant panda breeding. Jennifer L. Keating (Appl. Animal Ecology, Inst. for Conservation Res., San Diego Zoo Global, 15600 San Pasqual Valley Rd., Escondido, CA 92027, jkeating@sandiegozoo.org), Tracey K. Brown, Nancy G. Caine (California State Univ. San Marcos, San Marcos, CA 92096), Ann E. Bowles (Hubbs-SeaWorld Res. Inst., San Diego, CA 92109), Benjamin D. Charlton (Univ. of Vienna, Vienna, Austria), and Ronald R. Swaisgood (Inst. for Conservation Res., San Diego Zoo Global, Escondido, CA 92027)

Silent most of the year, giant pandas (*Ailuropoda melanoleuca*) engage in sustained and diverse vocal behavior during their brief annual reproductive window. These vocalizations suggest a complex communication repertoire and play an important role in facilitation of mating. To increase our understanding of their vocal communication, we analyzed male and female vocalizations during breeding interactions. Digital audio recordings were collected during breeding seasons of 2008, 2009, and 2011 at zoological facilities in San Diego, California, and China, and were processed using SOUNDTRACK PRO 2.0 and RAVEN PRO 1.4 software. Seven types of vocalizations were identified ("bark," "moan," "growl," "squeal," "chirp," "bleat," and "copulation call"). We compared vocalizations from 32 confirmed copulations and 37 non-copulatory breeding sessions of 31 individuals (24 females, 7 males). They revealed differences in vocalizations produced before, during, and after intromission. During intromission, the male produces a copulation call that distinguishes successful breeding encounters from unsuccessful pairings acoustically. This call has not been described previously. The results shed light on the motivational and functional significance of panda vocalizations during mating encounters. They can be used in captive breeding programs to promote reproduction in this endangered species. [Work supported by ZSSD, CSUSM, and CCRCGP.]

2:45

3pAB6. Behavioral audiogram of the giant panda (*Ailuropoda melanoleuca*): Preliminary results. Megan A. Owen, Jennifer L. Keating (Appl. Animal Ecology, Inst. for Conservation Res., San Diego Zoo Global, 15600 San Pasqual Valley Rd., Escondido, CA 92027), Samuel L. Denes (The Penn State Univ.), Kathy Hawk, Juli Boroski, Angela Fiore (Collections Husbandry Sci. San Diego Zoo Global), and Ronald R. Swaisgood (Appl. Animal Ecology, Inst. for Conservation Res., San Diego Zoo Global)

We used behavioral techniques to assess the hearing sensitivity of four, critically endangered, giant pandas at the San Diego Zoo. Study subjects included one adult male (age 19), two adult females (ages 5 and 19), and one sub-adult female (age 3). We used a down-up staircase presentation order and a go/no-go response paradigm and thus far have measured hearing thresholds between 250 Hz and 31.5 kHz. Test stimuli were 500 ms shaped tones, and catch trials represented 30% of presentations. All subjects were trained using positive reinforcement. Preliminary results suggest that giant pandas have good hearing sensitivity between 8 and 14 kHz, and best sensitivity was centered at 12.5 kHz. Low frequency hearing sensitivity declined at 250 Hz for all subjects. All bears retained functional hearing at 31.5 kHz: the younger females could hear tones as low as 15 dB, and the adults could hear to 25 dB. Preliminary results suggest that panda hearing sensitivity is similar to that of other terrestrial carnivores studied to date. Hearing sensitivity data will enhance the understanding of how anthropogenic noise may impact both free-ranging and captive giant pandas.

Session 3pAO

Acoustical Oceanography: Munk Award Lecture

Martin Siderius, Chair
Electrical and Computer Engineering, Portland State Univ., 1900 S.W. 4th Ave., Portland, OR 97201

Chair's Introduction—2:10

Invited Paper

2:25

3pAO1. Underwater acoustics and acoustical oceanography. William A. Kuperman (Scripps Inst. of Oceanogr., Marine Physical Lab., MC0238, 9500 Gilman Dr., La Jolla, CA 92093-0238, wkuperman@ucsd.edu)

Though underwater acoustics (UW) and acoustical oceanography (AO) have different goals, their overlap often makes efforts in these areas indistinguishable. In this talk I emphasize their similarities while also discussing their different approaches. Topics to be briefly covered in this review will include the environmental acoustic aspects of propagation, noise, and inversion with examples from modeling and experiments. Among the interesting outcomes of the differences between these fields is that the emphasis on inversion in AO has increased the accuracy requirements for UW.

Session 3pBA

Biomedical Acoustics: General Biomedical Ultrasound

Robert J. McGough, Chair
Electrical and Computer Engineering, Michigan State Univ., 2120 Engineering Bldg., East Lansing, MI 48824

Contributed Papers

1:45

3pBA1. Transthoracic *in vivo* measurements of porcine myocardial viscoelasticity using Lamb wave dispersion ultrasound vibrometry. I. Z. Nenadic, M. W. Urban, C. Pislaru, and J. F. Greenleaf (Ultrasound Res. Lab., Mayo Clinic College of Medicine, 200 1st Street SW, Rochester, MN 55905)

Diastolic dysfunction is characterized by the stiffening of the left-ventricular myocardium. An imaging technique capable of quantifying viscoelasticity of the left-ventricle would aid clinicians in evaluating diastolic function. Lamb wave dispersion ultrasound vibrometry (LDUV) is an ultrasound-based method for measuring viscoelasticity of plate-like materials by exciting Lamb waves and measuring change of wave velocity as a function of frequency (dispersion). Lamb wave dispersion equation is fit to the dispersion data to estimate mechanical properties. We report *in vivo* transthoracic studies aimed at quantifying elasticity and viscosity of a beating porcine left-ventricle using LDUV. A single ultrasound probe operating at 5 MHz was used for impulse excitation in the myocardium and to track the wave motion. A Fourier space-time analysis of the motion was used to obtain Lamb wave velocity dispersion. ECG-gated transthoracic *in vivo* measurements of group velocity, elasticity, and viscosity throughout a single heart cycle were obtained. Group velocity, elasticity, and viscosity in the frequency range from 50 to 500 Hz increased by at least two-fold from diastole to systole, consistent with contraction and relaxation of the myocardium.

2:00

3pBA2. Evaluation of the power-law impulse response for liver in the time- and frequency-domains. Christopher T. Johnson and Robert J. McGough (Dept. of Elec. and Comput. Eng., Michigan State Univ., 1213 Eng. Bldg., East Lansing, MI 48824, mcgough@egr.msu.edu)

Ultrasound attenuation in biological media often follows a frequency-dependent power-law relationship. Power-law attenuation is accompanied by dispersion in which phase velocity also changes as a function of frequency. The power-law wave equation has exact time- and frequency-domain Green's function solutions that are used in numerical evaluations of the Rayleigh–Sommerfeld diffraction integral. These Green's functions contain stable probability density functions that are evaluated in the time-domain using the STABLE toolbox and in the frequency-domain by evaluating the characteristic function of a stable distribution. The impulse response for a circular piston is evaluated on-axis in the time- and frequency-domain using values for human liver. The results show the accuracy of the time-domain impulse response calculation is dependent upon

adequate spatial sampling of the piston face. The frequency-domain impulse response exhibits aliasing caused by wrap around of the heavy tail of the stable distribution. Frequency-domain accuracy is dependent upon the spatial sampling of the piston face and the density of the frequency samples. Numerical evaluations show that the frequency- and time-domain calculations converge to the same result. [This work was supported in part by NIH Grant R01 EB012079.]

2:15

3pBA3. Frequency domain calculations of pulse-echo ultrasound signals with the fast nearfield method. Robert J. McGough (Elec. and Comput. Eng., Michigan State Univ., 2120 Eng., East Lansing, MI 48824, mcgough@egr.msu.edu)

Simulations of pulse-echo signals transmitted and received by an ultrasound phased array are evaluated in the frequency domain using FOCUS, and the results are compared with the output of Field II. The frequency domain simulation approach in FOCUS calculates the fast Fourier transform of the input signal, evaluates the individual frequency components of the transmit and receive pressure transfer functions using the fast nearfield method, and then computes the inverse fast Fourier transform of the product to obtain a numerical representation of the received time signal. With this approach, synthetic aperture signals are simulated in MATLAB for each pair of transmit and receive elements for three transmit elements and sixteen receive elements. Each element is excited with a 3 cycle Hanning-weighted input pulse with a 3 MHz center frequency. The temporal sampling of the computed signal in FOCUS is 12 MHz. To achieve approximately the same accuracy, Field II requires a temporal sampling of 4 GHz. Examples of simulated radio-frequency signals, the envelopes of these signals, and the associated numerical errors will be demonstrated for each method, and formulas for converting the pulse-echo outputs generated in FOCUS and Field II into equivalent quantities will be shown.

2:30

3pBA4. Estimation of two-dimensional strain rate based on high frame rate ultrasound imaging method. Hong Chen and Jian-yu Lu (Dept. of Bioengineering, Univ. of Toledo, 2801 W. Bancroft St., Toledo, OH 43606)

Strain rate (SR) measurement of heart tissue based on ultrasound images provides useful information of tissue hardness for diagnosing heart diseases. However, current SR estimation methods utilizing speckle tracking technique are based on conventional delay and sum (DS) imaging method, which causes skewed heart image resulting in inaccurate SR. To overcome the problem, a method to combine high frame rate (HFR) imaging method with speckle tracking technique was proposed. Using only one or a few transmissions for each image; compared with 91 for DS, new method can get a snapshot of moving targets, avoiding the skewing problem in DS. Two studies, with simulated and experimental echo data, respectively, were performed to verify the method. Both plane wave and limited diffraction beam (LDB) were studied for HFR. Both SR estimations in lateral and axial directions were calculated for the new and conventional ultrasound imaging methods. Results show that the new method has comparable or lower velocity errors than DS and more accurate SR, especially in lateral direction. Moreover, it can measure high velocity for other applications such as blood flow measurement. With the full view of heart image, SR of interest can be localized and then accurately estimated.

2:45

3pBA5. Transducer designs and simulations for high frequency scanning acoustic microscopy for applications in exploring contrast mechanism and the mechanical properties of biological cells. Yada Juntarapaso, Richard L. Tutwiler (Graduate Program in Acoust., The Penn State Univ., Univ. Park, PA 16802), and Pavlos Anastasiadis (Univ. of Hawaii, Honululu, HI 96822)

Scanning acoustic microscopy (SAM) has been extensively accepted and utilized for acoustical cellular and tissue imaging including measurements of the mechanical and elastic properties of biological specimen. SAM provides superb advantages: it is a noninvasive method; it can measure mechanical properties of biological cells or tissues; and fixation/chemical staining is not necessary. The first objective of this research is to develop a program for simulating the images and contrast mechanism obtained by high-frequency SAM. Computer simulation algorithms based on MATLAB® were built for simulating the images and contrast mechanism. The mechanical properties of HeLa and MCF-7 cells were computed from the V(z) measurement data. Algorithms for simulating V(z) responses involved calculation of the reflectance function and were created based on ray theory and wave theory. The second objective is to design transducer arrays for SAM. Theoretical simulations based on Field II programs of the high frequency ultrasound array designs were performed to enhance image resolution and volumetric imaging capabilities. The new transducer array design will be state-of-the-art in improving the performance of SAM by electronic scanning and potentially providing a four-dimensional image of the specimen. Phased array beam forming and dynamic apodization and focusing were employed in the simulations.

Session 3pEA

Engineering Acoustics and Biomedical Acoustics: Micromachined Acoustic Transducers II

Neal Hall, Cochair
Electrical and Computer Engineering Dept., Univ. of Texas at Austin, 1 University Station, Austin, TX 78712

Won-Kyu Moon, Cochair
Dept. of Mechanical Engineering, Pohang Univ. of Science and Tech., Pohang, 790-784, Korea

Contributed Papers

1:00

3pEA1. A high-dispersion regime of the zero-order symmetric Lamb wave mode for ultrasonic nondestructive evaluation. Li-Feng Ge (Anhui Univ., 3 Feixi Rd., Bldg. 166, Rm. 304, Hefei, Anhui 230039, China, lfge@ahu.edu.cn)

The zero-order symmetric Lamb wave mode (S0 mode) has been less studied than antisymmetric one (A0 mode). The S0 mode excited by micromachined electrostatic airborne ultrasonic transducers can be used for nondestructive evaluation of multilayer or composite materials, which deserves special attention. The dispersion curve of the S0 mode is investigated in depth and determined accurately by a three dimensional Plot Method presented previously [Ge, J. Acoust. Soc. Am. **126**(4), 2281 (2009); Proc. Meet. Acoust. **8**, 065003 (2011)]. It is revealed that as the product of the transverse wave number and thickness increases from a low limit to infinitive the phase velocity of the S0 mode decreases from transverse wave velocity to surface acoustic wave velocity. The low limit determined is 3.46 for Poisson ratio 0.34, and will be 3.31 and 3.05 for 0.28 (steel) and 0.17 (silicon), respectively. Also, it is seen that at a small regime over the limit the S0 mode is highly dispersive. Further, an approximate formula to determine the dispersion relation of the regime is derived analytically for the convenience of practical applications. Since the zero-order mode carries more energy than higher-order modes, the high-dispersion regime is significant particularly for ultrasonic nondestructive evaluation. [Work supported by NSFC (60774053).]

1:15

3pEA2. Split domain antiresonance in micromachined lithium niobate. Igor Ostrovskii and Lucien Cremaldi (Dept. of Phys. and NCPA, University of Mississippi, 108 Lewis Hall, University, MS 38677, iostrov@phy.olemiss.edu)

The micromachined periodically poled LiNbO3 (PPLN) demonstrates acoustic superlattice properties. Different acoustic modes in PPLN wafer have their stop-bands with low FL and upper FU cutoff frequencies. The micromachined transducers based on such structures operate at frequencies near FL and FU; they have a strong domain resonance-antiresonance when acoustic half-wavelength is close to domain length. In this work, we investigate structures with 300- and 450-micron long domains micromachined in a 0.5-mm-thick Z-cut lithium niobate wafer. The metal electrodes are deposited onto multi-domain structures having up to 90 total inversely poled domains. Experimentally, two modes of operation are investigated: (1) acousto-electric current excitation of domain vibrations when rf current passes through the whole multidomain structure and (2) plate-waves excitation and detection at two opposite ends of domain pattern when acoustic vibration travels through the multidomain pattern. In both cases, the split antiresonances are observed, and they are characterized by two main minima coinciding with the FL and FU frequencies. The difference (FL – FU) constitutes the stop-band for propagating zero antisymmetric mode, at which PPLN transducer operates. The experimental data are in agreement with theoretical calculations. Possible application of the split antiresonance effect for micromachined ultrasonic transducers is discussed. [This work is made possible in part due to the research grant "Nonlinear vibrations of piezoelectric resonators," UM, 2011.]

1:30

3pEA3. Micromachined ultrasonic transducers and nonclassical nonlinear effects due to domains. Igor Ostrovskii and Andriy Nadtochiy (Dept. of Phys. and NCPA, Univ. of Mississippi, University, MS 38677, iostrov@phy.olemiss.edu)

Two-dimensional ultrasonic transducers and delay lines fabricated on micromachined $LiTaO_3$ and $LiNbO_3$ plates are demonstrated. The 0.5-mm-thick commercial wafers are inversely poled by applying an external electric field to get periodic and aperiodic multidomain structures. The metal electrodes are deposited on the structures to excite ultrasonic vibrations by applying radio frequency voltage. The domain lengths are in a broad range from 16 μm to 1 mm with corresponding frequencies from 347 to 3 MHz. The finite element method is used for computer simulation of the micromachined transducers. Experimental results are in agreement with theoretical calculations. All transducers have a so called domain resonance and operate at frequencies near this resonance. The highest vibration amplitude is usually observed when acoustic wavelength is two times greater than a single domain length. The multidomain structures have their own nonclassical nonlinear properties, which may be explained by domain kinetics and their collective behavior. For instance, an efficiency of transduction may depend on such physical effects like domain reverberations and so called stop-bands in an acoustic superlattice, which in turn are specific functions of frequency and other conditions of excitation. Possible applications of the piezoelectric micromachined transducers and vibrators are discussed. [This work is made possible in part due to the research grants "Nonlinear vibrations of piezoelectric resonators," UM, 2011; "Multidomain plate acoustic wave devices," UM, 2007.]

1:45

3pEA4. Micromachining of acoustic transducers and arrays. Zhihong Wang, Xixiang Zhang, and Xianbin Wang (Adv. Nanofabrication Core Lab., King Abdullah Univ. of Sci. and Technol., Thuwal 23955-6900, Saudi Arabia, zhihong.wang@kaust.edu.sa)

Microelectromechanical systems (MEMS) technology has been used to fabricate miniature acoustic transducers for a variety of applications in different media and frequency ranges. The consistency in performance of individual transducer afforded by batch-fabrication also makes it feasible to employ MEMS transducer arrays in beam forming or beam steering technique. This paper will first introduce our own research work on micromachining of piezoelectric acoustic transducers, including sol–gel thin film piezoelectric microphone for audio application; composite thick film piezoelectric micromachined ultrasonic transducer array for biomedical imaging; and transducer arrays fabricated by Si-PZT bonding technology for

hydrophone and audio beam applications. The preliminary results on receiving and transmitting performance of the fabricated transducers and arrays will also be reported. In addition, a scanning acousto-optic microscope, which uses a single micromachined acousto-optic sensor and interferometry, will also be introduced. With this technique, it is possible to map a spatial sound field distribution at micrometer resolution.

2:00

3pEA5. A micro-machined microphone based on field-effect-transistor and electrets. Kumjae Shin (Dept. of Mech. Eng., POSTECH, PIRO 416 Hyoja-Dong, Nam-Gu, Gyungbuk, 790-784 Pohang, South Korea, forhim13@postech.ac.kr), Yub Je (PIRO 416 Hyoja-Dong, Gyungbuk, 790-784 Pohang, South Korea), Haksue Lee (Jinhae, Gyungbuk, South Korea), James Edward West (Johns Hopkins Univ.), and Wonkyu Moon (PIRO 412 Hyoja-Dong, Gyungbuk, 790-784 Pohang, South Korea)

Micro-machined microphones are attracting attention of industry because of their benefit of size over conventional ones. Since most of micro-machined microphones are capacitive sensors, the sizes of their electrodes determine the low frequency noise level that increases with inverse of frequency (1/f). Therefore, the size of microphone itself becomes larger than one that can be fabricated. Here, we introduce a micro-machined microphone that can overcome the limit of capacitive microphones. The proposed microphone is composed of a field-effect-transistor (FET) and an electret. The difference between the conventional electret capacitive microphones and the proposed microphone may be the transduction mechanism: The change in the position of an electret causes the change in electric field on the gate of FET. Compared with capacitive transduction, the resistive channel of FET can be designed to have low sensor impedance, and subsequently have low impedance at low frequency. To make experimental specimen, FET onto membrane and electret was fabricated with conventional metal-oxide-semiconductor fabrication process and micromachining process, respectively. The FET membrane chip and the electret chip were assembled. Simple current to voltage converter was applied as a pre-amplifier. Its feasibility to apply low frequency acoustic sensor will be proved by simulation and experimental results.

2:15

3pEA6. The piezoelectric micromachined ultrasonic transducer arrays as a high-intensity sound generator: An experimental analysis. Yub Je (Dept. of Mech. Eng., POSTECH, San 31, Hyoja-dong, Nam-gu, Pohang, Gyungbuk, Republic of Korea, effortjy@postech.ac.kr), Haksue Lee (Agency for Defense Development, Jinhae, Gyungnam 645-016, Republic of Korea), and Wonkyu Moon (POSTECH, Pohang, Gyungbuk, Republic of Korea)

High-intensity sound generation in air with high efficiency is usually difficult, since the acoustic impedance of air is generally much smaller than that of the transducers. In an earlier study by [H. Lee *et al*., J. Acoust. Soc. Am. **125**, 1879-1893 (2009)], the potential for high-efficiency sound generation of a piezoelectric micromachined ultrasonic transducer (pMUT) was examined theoretically and experimentally. A thin-film transducer such as pMUT can generate sound with improved mechano-acoustic efficiency since the internal mechanical impedance of the thin-film structure can be reduced. The highly efficient characteristics of a single pMUT, however, cannot easily be used to yield high-intensity sound from pMUT array, due to variations between units in membrane size, driving voltage, and acoustic loading. In this work, a pMUT array consisting of efficient PZT uni-morph elements was designed and fabricated. The unit-to-unit variations of the pMUT array are analyzed by measuring velocity amplitude and phase of each unit transducer. The result shows that the radiated sound from pMUT array is greatly reduced due to the unit-to-unit variations of the pMUT. To eliminate the problems, uniformity control of fabrication process, optimal design of electrode pattern, and alignment method of an array pattern are considered for high-intensity sound generation.

2:30

3pEA7. Digital beam-steering of parametric array sound beams using piezoelectric micromachined ultrasonic transducers. Yub Je (Dept. of Mech. Eng., San 31, Hyoja-dong, Nam-gu, Pohang, Gyungbuk, 790-784, Republic of Korea, effortjy@postech.ac.kr), Haksue Lee (Agency for Defense Development, Jinhae, Gyungnam 645-016, Republic of Korea), and Wonkyu Moon (Gyungbuk 790-784, Republic of Korea)

In a previous study [H. Lee *et al*., J. Acoust. Soc. Am. **125**, 1879–1893 (2009)], a parametric array (PA) transducer in air using micromachined ultrasonic transducers (MUT) was examined as an ultrasonic ranging sensor. It was shown that the piezoelectric micromachined ultrasonic transducer (pMUT) may be effective for PA ultrasonic ranging sensors. Since the pMUT are usually used in their array, PA source using pMUT can steer its directional sound beam by manipulating phases of radiator in the array. The beam steering capability of the PA source can provide very useful function for parametric loudspeakers as well as directional ultrasonic range sensors. In this work, 16-channel pMUT array for digital beam-steering of parametric array was designed and fabricated. Each channel of the pMUT array consisted of 9 PZT unimorph elements. The two resonance frequency-type pMUT units are designed for generating two primary beams. Beam-steering of each primary beam was controlled separately by applying complex weighting to each channel. An acoustic experiment verified the PA beam-steering of the pMUT. The result shows that the proposed pMUT is suitable for digital beam-steering of parametric array and that it is also useful for the parametric loudspeaker and the PA ultrasonic range sensor.

2:45

3pEA8. The performance enhancement of the hydrophone based on the piezoelectric gate of field effect transistor for low frequency application. Min Sung, Kumjae Shin (PIRO 416, Pohang Univ. of Sci. and Technol., San31, HyoJa-dong, Nam-gu, Pohang-city, KyungBuk, South Korea, smmath2@postech.ac.kr), and Wonkyu Moon (PIRO 405, Pohang Univ. of Sci. and Technol., Pohang-city, KyungBuk, South Korea)

A hydrophone based on the transduction using the electric field of piezoelectric ceramic directly applied on the gate of field effect transistor was proposed, and the feasibility was shown in the year of 2010. Although the feasibility was proved with proper working condition, the fabricated device had some problems on the stability, noise, and sensitivity. The electric field generated from the piezoelectric ceramic in thickness mode, which receives the acoustic pressure from the pressure amplifying head mass structure, modulates the channel current of field effect transistor. The parametric analysis for the transduction was done for the performance enhancement. To realize stable and highly sensitive modulation, the field effect transistor was designed and fabricated with improved gate insulation layer. The passivation for the field effect transistor was also performed to protect the device from external factors and reduce the noise. The sensitivity evaluation setup using the free field calibration method was modified for more accurate measurement. The evaluation results for the improved device are to be presented. [Research supported by MRCnd.]

Session 3pED

Education in Acoustics: Acoustics Education Prize Lecture

Carl J. Rosenberg, Chair
Acentech, 33 Moulton St., Cambridge, MA 02138

Chair's Introduction—2:10

Invited Paper

2:15

3pED1. Teaching architectural acoustics to architecture, architectural engineering, and music students. Robert C. Coffeen (School of Architecture, Design & Planning, Univ. of Kansas, 1465 Jayhawk Blvd., Lawrence, KS 66045, coffeen@ku.edu)

A rewarding career in architectural acoustics has provided the opportunity to teach as a faculty member of the School of Architecture, Design and Planning at the University of Kansas. This presentation will discuss methods and techniques for teaching the basics of architectural acoustics to architecture students so that they might apply these basics to their building designs, for teaching acoustic basics to music students so that they will appreciate and properly use venues for music performance and rehearsal, and for teaching architecture and architectural engineering students interested in building acoustics and who desire to have a career in professional acoustical consulting. These methods and techniques are built on current acoustic knowledge, measurements, and analysis-measurement computer software; on 35 yr of acoustical consulting experience; on opportunities for assisting with architecture studios, for teaching established courses and portions of courses, and for creating new courses with such opportunities provided by the architecture and the architectural engineering faculty and administration; by the Acoustical Society of America with teaching opportunities such as provided by the annual student design competitions; and by many excellent architecture and architectural engineering students. Specific methods, techniques, presentations, course syllabi, etc., will be discussed.

Session 3pIDa

Interdisciplinary: Hot Topics in Acoustics

Peter Gerstoft, Chair
Scripps Inst. of Oceanography, Univ. of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0238

Invited Papers

1:00

3pIDa1. Hands-on acoustics for public school students. Uwe J. Hansen (Dept. of Chemistry and Phys., Indiana State Univ. Terre Haute, IN 47809) and Wendy Adams (Univ. of Northern Colorado, Greely, CO 80639)

Since the appointment of an Education Coordinator, the hands-on equipment purchased by ASA, as well as material donated by various Science Education companies, has been sorted and prepared for safe and easy shipping. It is ready for continuing use at the ASA semiannual meetings and within limits will also be accessible for use by ASA members in connection with various events at locations throughout the country. The general hands-on philosophy and a number of the experiments included in the material will be discussed and demonstrated. A detailed description of the individual experiments, as presented in a student hand-out, will also be distributed. The "Acoustics Activity Kit for Teachers" will also be demonstrated and discussed.

1:20

3pIDa2. Hot topics in physical acoustics. Veerle Keppens (Univ. of Tennessee, Materials Sci. and Eng., Knoxville, TN 37996)

Understanding the propagation and interaction of acoustic waves in "unconventional" systems is one of the main focus areas of physical acoustics, where unconventional may indicate that the system is far from thermodynamic equilibrium, poorly understood, newly

discovered, or a combination thereof. In this talk, I will attempt to give a few specific examples of recent contributions from the field of physical acoustics to a better understanding of "hot" materials such as Pu and pnictide superconductors. Additional examples from current efforts in physical acoustics will be used to illustrate the breadth of the field and show how physical acoustics is closely tied to many other technical areas within the Society.

1:40

3pIDa3. Hot topics in noise: Wind turbines. Kenneth Kaliski (Resource Systems Group, Inc., 55 Railroad Row, White River Junction, VT 05001, kkaliski@rsginc.com)

Since 2000, the installed capacity of wind energy in the U.S. increased seventeen-fold, with the greatest increases in recent years. Today, we commonly find terrestrial wind farms with individual towers of 80–100 m and rotor diameters up to 112 m. The number of wind farms is projected to increase, as many states are adopting renewable energy portfolio standards in an effort to help combat climate change. As wind farms grow, there are inevitably more potential conflicts related to the impacts of the noise generated by the turbines. Noise has taken center stage in both proceedings for proposed wind farms and complaints from some operating wind farms. This talk will review the major issues regarding wind turbine noise, including sound emissions, sound propagation and modeling, sound monitoring, human perception, and regulation. Areas of controversy will be explored, including infrasound and low frequency sound, amplitude modulation, and health impacts.

WEDNESDAY AFTERNOON, 2 NOVEMBER 2011 ROYAL PALM 1/2, 1:00 TO 3:15 P.M.

Session 3pIDb

Interdisciplinary: Demystifying Standards

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

Susan B. Blaeser, Cochair
Acoustical Society of America Standards Secretariat, 35 Pinelawn Rd., Ste. 114E, Melville, NY 11747

Invited Papers

1:00

3pIDb1. Standards 101. Paul Schomer (Schomer and Assoc. Inc., 2117 Robert Dr. Champaign, IL 61821, schomer@SchomerAndAssoc..com)

The Acoustical Society of America (ASA) was founded in 1929 and the standards program of the Acoustical Society began in 1930. It followed the establishment of meetings and the journal. Currently, only meetings attract greater participation than does the standards program. Although standards have been an integral part of the ASA for 81 yr, it still remains a mystery to many members. This paper introduces the special session on standards and describes the basic organization and operation of the standards program. It is followed by case studies highlighting the standards process and the reasons organizations of different types and sizes find it worthwhile to participate. While this session primarily has a U.S. perspective, it also includes a paper presenting a non-U.S. perspective.

1:15

3pIDb2. Modern tools for improving the development of acoustical standards. Christopher J. Struck (CJS Labs., 57 States St., San Francisco, CA 94114, cjs@cjs-labs.com)

The development of acoustical standards has in the past largely followed on the trailing edge of technology. Given the progressively more rapid development of new technology, it is critical that new standards be developed when needed in the timeliest manner possible. Furthermore, participants in working groups are volunteers with limited time available for this important work. Budgetary constraints may also limit travel to in-person meetings for many persons otherwise interested in participating and whose practical experience is essential to the process. On-line meeting and collaboration tools enable shorter, more effective, and more frequent meetings to move draft standards more quickly to a ballot-ready document. Documents can be edited collaboratively in real time using standard mark-up tools for immediate feedback from participants. This also enables participation across time zones. The use of a password protected "cloud network" ftp site for working group documents (e.g., drafts, reference documents, meeting minutes, etc.) eliminates unnecessary e-mail traffic with large attachments and enables participants to access documents at any convenient time. These tools will be described and demonstrated to show the contemporary standards development process in action.

1:30

3pIDb3. An equipment manufacturer's perspective of acoustical standards. Stephen J. Lind (Ingersoll Rand, Trane Bldg. 12-1, 3600 Pammel Creek Rd., La Crosse, WI 54601)

As an HVAC manufacturer, it is our goal to create safe, comfortable, and efficient environments (i.e., classrooms, health care facilities, offices, etc.). Standards are useful in gaining agreement regarding the appropriate sound levels for these spaces and establishing how to verify that these levels are met. Regular interaction and participation in writing the standards helps to ensure that all are aware of the requirements and it also allows participants to provide input on what is practical. Participating in the process also helps to prevent adversarial relations between the parties involved in the design and use of the equipment. Standards also provide the technical basis for which manufacturers and customers can make a valid comparison of different products. The information provided is useful in the design process. Sound power of the equipment is a commonly used metric. Standardizing sound power measurement methods reduces the customer's risk by making sure the published sound levels are representative of the equipment as it is intended and gives a defined expectation of repeatability. Thus, participating in the standards process, we help to ensure that the measurement methods are practical for the intended equipment.

1:45

3pIDb4. The standards process from the perspective of a government scientist. Arnold G. Konheim (U.S. Dept. of Transportation, 1200 New Jersey Ave., SE, Washington, DC 20590)

Through its operating administrations, the U.S. Department of Transportation issues regulations covering the safety, security, health, and environmental protection of all modes of transportation. Many of these regulations incorporate consensus standards as required under the National Technology Transfer and Advancement Act of 1995, which directs federal agencies to generally use standards developed by voluntary consensus bodies. Particular examples of the role of consensus standards in DOT regulations are discussed in this presentation.

2:00

3pIDb5. Taking ASA/ANSI Standards to ISO. Michael Bahtiarian (Noise Control Eng., Inc., 799 Middlesex Turnpike Billerica, MA 01821, mikeb@noise-control.com)

The author served as the chairman of the working group that completed the first voluntary consensus standard for measurement of underwater noise from ships (ANSI/ASA S12.64-2009/Part 1, Quantities and Procedures for Description and Measurement of Underwater Sound from Ships, Part 1; General Requirements). Within the last year, an effort to bring this standard to the international arena has started. The S12.64 standard is an entirely new document without any prior written standards to use as a template, however, the methodology was previously used by the U.S. Navy and NOAA. This session will address the process of organizing and developing a new ASA/ANSI standard and then taking such a standard to International Standards Organization (ISO). It will address organizational challenges of working with experts from industry, government, and academia, both from the United States. and overseas. It will cover issues related to planning and executing physical and web enabled meetings. Lastly, it will address the similarities and differences of the standards development process under ISO.

2:15

3pIDb6. Tower of Babel, or why bother about international standards? Osten Axelsson (Passvaegen 30, SE-14753 Tumba, Sweden)

While a vast nation like the USA has the capacity to be self-sufficient, many countries lack this privilege. Take Sweden as an example, a small country in northern Europe with a population of 9 million. Swedes are proud to be international. And they should, because how could a nation, which since the days of the Vikings has depended on international trade, sustain itself without a global economy. International standards support the development within this global economy, just like English as business language facilitates global collaboration. Imagine humanity without these common frames of reference.

2:30

3pIDb7. International standards development and the U.S. Technical Advisory Group process. Susan B. Blaeser (Acoust. Society of America Standards Secretariat, 35 Pinelawn Rd., Ste. 114E, Melville, NY 11747, sblaeser@aip.org)

As industry becomes increasingly global the importance of international standards increases, too. How can U.S. companies, government agencies, and other organizations ensure that their voices are heard and their interests are protected? The U.S. Technical Advisory Group (U.S. TAG) provides the only avenue for U.S. stakeholders to provide input to technical committees in the International Organization for Standardization and the International Electrotechnical Commission. The Acoustic Society of America currently administers nine of these U.S. TAGs. This paper discusses TAG membership and participation in international standards development.

2:45–3:15 Panel Discussion

Session 3pNS

Noise, Psychological and Physiological Acoustics, and Speech Communication: New Advances in Bone and/or Tissue Conduction of Noise

Richard L. McKinley, Chair
Air Force Research Lab., 2610 Seventh St., Wright-Patterson AFB, OH 45433-7901

Chair's Introduction—1:00

Invited Papers

1:05

3pNS1. Investigation of the relationship between the vibration patterns of the skull and bone-conducted sound. Margaret Wismer (Dept. of Phys., Bloomsburg Univ., Bloomsburg, PA 17815, mwismer@bloomu.edu) and William O'Brien (Univ. of Illinois Urbana-Champaign)

Analytic and numerical models are used to evaluate acoustic energy converted into bone conducted sound that reaches the middle and inner ear. Sound impinging upon the skull, from an outside source, is channeled into surface waves on the outside of the skull. These waves have components in both the solid bone and the background medium of air, travel at much slower speeds than longitudinal sound speed for bone and have wavelengths smaller than those of an acoustic signal existing solely in bone or in the cranial cavity. Frequencies, at which an integer number plus one half of surface wave wavelengths fit around the circumference of the sphere, cause resonant vibrations. The added one half is due to phase matching surface waves at the poles. The relatively slow sound and short wavelengths mean resonance frequencies for the skull are lower than if the acoustic energy were confined to standing waves within the cranial cavity wherein wavelengths are longer. At acoustic frequencies skull vibrations are analogous to lowest order flexural modes of a fluid-loaded elastic sphere. Numerical models suggest bone's conducted sounds are confined to the skull surface with wave speeds much lower than speed of sound for boney or soft tissue.

1:30

3pNS2. Bone and/or tissue conducted noise: Implications for advanced hearing protection. Hilary L. Gallagher (USAF/AFRL 711 HPW/RHCB, 2610 Seventh St. Bldg. 441, WPAFB, OH 45433), Melissa A. Theis (Oak Ridge Inst. for Sci. and Education, TN 37831), and Richard L McKinley (USAF/AFRL 711 HPW/RHCB, OH 45433)

Military personnel working in various high noise environments may be exposed to continuous noise levels reaching 150 dB. At those levels, bone and tissue conduction pathways become the dominate pathway for sound transmission to the cochlea. Accordingly, hearing protection devices designed to attenuate noise transmitted via air conduction pathways may not be sufficient for meeting hearing conservation requirements. The goal of adequately protecting personnel in these types of environments requires a better understanding of the bone and/or tissue conduction flanking pathways, the susceptibility of the cochlea to bone and tissue conducted energy, and the accompanying mitigation strategies. This experiment investigated the linearity of air conducted noise to the transmission of bone, tissue, and bone/tissue conducted noise. Specially designed bone and tissue conduction drivers, which primarily isolate and excite the respective desired pathways, were used to conduct a loudness matching study. Preliminary findings from this study will be discussed, as well as the implications for development of more effective hearing protection and potential needs for creating new safety requirements based on bone and tissue conducted stimulation. [Work sponsored by AFOSR.]

1:55

3pNS3. Protecting beyond the bone-conduction limit. Anthony J. Dietz, William E. Audette, Jed C. Wilbur, and Christian H. Passow (Creare Inc., P.O. Box 71, Hanover, NH 03755, ajd@creare.com)

Workers operating in extreme noise may need levels of hearing protection that are beyond that possible with double hearing protection comprising earplugs and circumaural hearing protectors. In such noise fields, sound conducted along bone-conduction transmission paths that bypass the ear canal can be sufficient to cause hearing damage. To provide sufficient protection beyond this bone-conduction limit, hearing protectors must attenuate sound that is transmitted to the cochlea via bypass mechanisms. The design of a passive hearing protection helmet that provides protection beyond the bone-conduction limit is described here. The helmet was developed for Navy aircraft carrier deck crews who are exposed to extreme sound levels of 150 dB during aircraft launch operations. The helmet design was based on extensive measurements with human subjects and with a human head simulator built to measure bone-conducted sound. These measurements demonstrated that a helmet shell fitted with an edge seal that created an acoustic seal between the shell and the head was effective in attenuating bone-conducted sound. Measured attenuation data are presented in addition to fit and performance data from tests in the laboratory and the field. Lessons learned from this development effort are also discussed. [Work sponsored by the U.S. Navy].

2:20

3pNS4. Ambiguity in phoneme recognition when using a bone conduction microphone. Karl Buck and Vronique Zimpfer (APC, French German Res. Inst., 5 r Gal. Cassgnou, BP 70034, FR68301 St. Louis, France, karl.buck@isl.eu)

Bone conduction microphones are often promoted as good means for recoding voice signals in very noisy and/or harsh environments. However, it is reported in the literature that the speech intelligibility when using contact microphones is, in all noise conditions, worse than when using a boom microphone. Therefore, long term spectra of speech signals simultaneously recorded with bone and air microphones have been analyzed. This analysis shows, for all measured subjects, that the module of the transfer function between the signal recorded at the air-microphone and, because of this, at the contact microphone increases toward higher frequencies. The results also show large interindividual differences. In order to get more perception related information, a corpus of French vowels has been recorded simultaneously with air and contact microphone. This corpus has been used for a listening test aiming to show confusion between different vowels. The main confusions are for vowels having the same frequency of the first formant (e.g., [i][y][u]) which then are perceived as the central vowel. These confusions could explain the systematically lower intelligibility reported for speech when recorded with contact microphones. Planned experiments using plosive and fricative consonants should give more information about transfer mechanisms of bone conducted voice.

Contributed Papers

2:45

3pNS5. A simplified axi-symmetric finite element model of the human outer ear to determine the earplug induced auditory occlusion effect. Martin K. Brummund (Dept. of Mech. Eng., ETS, 1100 Rue Notre Dame O., Montreal, PQ H3C1K3, Canada, martin.brummund.1@ens.etsmtl.ca), Franck Sgard (IRSST, Montreal, PQ, H3A3C2, Canada), Yvan Petit, and Frédéric Laville (ETS, Montreal, PQ, H3C1K3, Canada)

Earplugs are a frequently used short-term solution for hearing conservation in the workplace environment. Due to limited auditory comfort, however, workers often only wear them for short periods of time and become prone to hearing loss. An important source of discomfort is the auditory occlusion effect, which expresses itself through the distortion of the wearer's voice and the amplification of physiological noises upon earplug insertion. Simplified numerical modeling can help to better assess and design earplugs, because it requires few system resources and is simpler in terms of numerical and experimental implementation than an equivalent complex model. This work describes a novel coupled linear elasto-acoustic two dimensional finite element (FE) model of the human outer ear. The model comprises the auditory canal as well as the bony, cartilaginous, and skin tissues whose material parameters were approximated using literature findings. The outlined model can compute the transfer functions between the sound pressure levels at the eardrum and a structure-borne excitation for both an unoccluded ear and an ear occluded by a molded earplug. Simulated occlusion effects are examined as a function of excitation, earplug, and insertion depth. Predicted model results are compared to literature findings and to findings obtained from an equivalent three dimensional FE-model.

3:00

3pNS6. Integrating speech enhancement with subband active noise control to improve communication in hearing protectors. Eric R. Bernstein, Anthony J. Brammer, Gongqiang Yu, Martin G. Cherniack, and Donald R. Peterson (Ergonomics Technol. Ctr., Univ. of Connecticut Health Ctr., 263 Farmington Ave., Farmington, CT 06030)

Many workers refuse to wear hearing protection devices (HPDs) because they would rather accept the health risks than sacrifice the ability to communicate with coworkers. Integrating active noise reduction (ANR) techniques with speech enhancement algorithms could solve these limitations of modern electronic HPDs. An adaptive delay feedforward subband structure has been implemented by forming parallel signal filtering and filter update paths for each frequency band. Subband ANR provides additional attenuation of environmental noise beyond that of passive HPDs within the lower frequencies associated with speech communication. The subband structure can also provide valuable information regarding the spectral content of the environmental noise that can be exploited to determine where additional power is needed in a communication channel to improve intelligibility. The system, initially developed in simulation, maintains a specified signal-to-noise ratio in each subband while simultaneously limiting the power added by the communication channel to below that associated with hearing damage. Speech Transmission Index models have been used to validate the improvements in speech intelligibility over typical passive and ANR communication headset designs. Preliminary results for a circumaural HPD constructed to implement the concept will be presented for comparison with the simulation. [Work supported by NIOSH (R01 OH008669).]

Session 3pSC

Speech Communication: Speech Rhythm in Production, Perception, and Acquisition I

Amalia Arvaniti, Chair
Dept. of Linguistics, Univ. of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0108

Chair's Introduction—1:00

Invited Papers

1:05

3pSC1. Speech rhythm analysis with empirical mode decomposition. Sam Tilsen (Dept. of Linguist., Cornell Univ., 203 Morrill Hall, Ithaca, NY 14853)

This paper presents a new approach to characterizing speech rhythm, based upon empirical mode decomposition (EMD) [Huang *et al*., Proc. R. Soc. London Ser. A **454**, 903–995 (1998)]. Intrinsic mode functions (IMFs) are obtained from EMD of a vocalic energy envelope of speech, which is a smoothly varying signal, representing primary vocalic resonance energy. EMD uses an iterative sifting process to decompose the signal into IMFs with zero mean and zero-crossings between extrema. Investigations of IMFs revealed that the last two IMFs appear to capture foot- and syllable-timescale oscillations in the envelope, respectively. EMD was applied to a seven-language corpus of speech previously used to compare languages using interval-based rhythm metrics [Ramus *et al*., Cognition **73**, 265–292 (1999)]. The ratio of signal power in the foot- and syllable-associated IMFs was used as metric of the relative influence of foot-based timing on speech. The performance of the IMF power ratio metric in distinguishing languages is comparable to analyses based on interval metrics. The method is argued to have the potential for broad applicability in speech research.

1:25

3pSC2. Comparing envelope- and interval-based rhythm metrics. Amalia Arvaniti (Dept. of Linguist., UC San Diego, 9500 Gilman Dr. #0108, La Jolla, CA 92093-0108, aarvaniti@ucsd.edu) and Sam Tilsen (Dept. of Linguist., Cornell Univ., 203 Morrill Hall, 159 Central Ave., Ithaca, NY 14853)

Numerous metrics have been developed in the attempt to characterize cross-linguistic differences in speech rhythm, particularly with regard to the rhythm class hypothesis, which holds that languages differ in whether they privilege regularity in timing of stress, syllables, or moras. This paper tests for consistency in the performance of different types of rhythm metrics, using speech corpora of English, German, Greek, Italian, Korean, and Spanish obtained from eight speakers of each language with three elicitation methods: read sentences, read running text, and spontaneous speech. Rhythm metrics tested were: interval-based metrics derived from durations of consonantal and vocalic intervals, low-frequency spectral analysis of the vocalic energy envelope, and a recently developed metric based upon the power ratio of foot and syllable intrinsic mode functions obtained from empirical mode decomposition of the vocalic envelope. For all languages, the metrics indicate that spontaneous speech exhibits more stress-timing like characteristics than read speech, having higher interval variability and more dominant stress-timescale periodicity in the envelope. Cross-linguistic differences emerged in some cases, but these were not entirely consistent across metrics and were affected by the elicitation method. Overall the data suggest that the elicitation effects (i.e., read versus spontaneous speech) are larger than differences between languages.

1:45

3pSC3. Speech cycling in Korean. Younah Chung (Dept. of Linguist., UCSD, 9500 Gilman Dr., La Jolla, CA 92093-0108)

This paper reports the results of a cycling experiment in Korean, a paradigm in which speakers produce short phrases in time with a metronome. It was hypothesized that in Korean the onsets of accentual phrases would act as beats in this task, playing the same part as stress plays in English; therefore, the accentual phase onsets would remain in the same phase within a cycle independently of their composition. Speakers read Korean sentences with three accentual phrases that had the same number of syllables or differed so one of the accentual phrases had twice as many syllables as the others; the composition of the syllables also varied between CV and CVC. The results so far suggest that speakers keep the accentual phrases in phase although the variation of syllable count and composition also affected phasing. This provides evidence that cycling is a viable task in Korean and supports our hypothesis about the role of the accentual phrase in Korean rhythm. Finally, the relative importance of the syllable cycle supports a view of rhythm that does not rest on the timing of one prosodic constituent, such as the accentual phrase, but on the relative salience of different levels of prosodic structure.

2:05

3pSC4. Speech rhythm in Akan/Twi: A preliminary experiment. Jonathan C. Anderson (Dept. of Linguist., Indiana Univ., Memorial Hall 322, 1021 E. Third St., Bloomington, IN 47405, andersjc@indiana.edu)

This study explores the rhythmic timing patterns of Akan/Twi, a West African tone language thought to be syllable-timed, using the Speech Cycling Task (Cummins & Port, 1998; Port, 2003, 2007; Tajima & Port, 2003). How rhythm appears in tone languages without

stress/accent is poorly understood. In the Speech Cycling Task, speakers were expected to place prominent elements within rhythmic modes, where specific syllables are pronounced more frequently in certain temporal regions. To uncover which syllables are considered rhythmically prominent, a previous tapping experiment (Darwin & Donovan, 1980; Donovan & Darwin, 1979; Purvis, 2009) was used in which subjects displayed entrainment between tapped beats and specific syllables (akin to stress-timing), rather than beat entrainment with all syllables. Prominent elements should also be resistant to temporal displacement when syllables are inserted between them and temporal compensation should occur when syllables can be deleted. The data included 20 phrases ranging from 4 to 8 syllables in length and four tone melodies (H, L, HL, and LH) repeated at varying rates. Results suggest subjects prefer certain rhythmic modes and that displacement and compensation occur such that rhythmic patterns change. Implications for the stress-timing/syllable-timing dichotomy and how tonal melodies affect rhythmic patterns are discussed.

2:25

3pSC5. Tone-based macro-rhythm from the perspective of prosodic typology. Sun-Ah Jun (Dept. of Linguist., UCLA, 405 Hilgard Ave. Los Angeles, CA 90095-1543, jun@humnet.ucla.edu)

In the autosegmental-metrical model of intonational phonology [Pierrehumbert, 1980, Ladd, 1996/2008], prosody is defined in terms of the prosodic structure of an utterance and the prominence relations within the structure. Jun (2005) proposed a model of prosodic typology based on the types of prominence-marking and rhythmic/prosodic units. Languages were categorized as Head-prominence when the head of a prosodic unit such as stress is marked prominent (e.g., English, Spanish, Greek), or Edge-prominence when the edge of a prosodic unit such as an accentual phrase (AP) is marked prominent (e.g., Korean), or Head/Edge-prominence when both the head and the edge are marked prominent (e.g., French, Bengali). The rhythmic/prosodic units covered both micro-rhythm (regularity due to the traditional rhythm category, e.g., stress-timed) and macro-rhythm (regularity due to a tonally defined prosodic unit, e.g., AP). Macro-rhythm was proposed to describe the rhythmic nature of a language where stress is not easily perceptible. In this talk, I will show that macro-rhythm is also crucial in describing sub-groups of Head-prominence languages as well as capturing the relationship between the complexity of tonal category and the types of prominence-marking across languages. Combining the prominence types and the f0-based macro-rhythm provides a better way to establish prosodic typology.

2:45–3:00 Panel-Discussion

Plenary Session and Awards Ceremony

Mardi C. Hastings, President
Acoustical Society of America

Presentation of Certificates to New Fellows

Keith A. Gillis
Mark Hasegawa-Johnson
Veerle M. Keppens
Masao Kimura
Michael J. Owren
Elizabeth A. Strickland
Alexander Sutin
Zhaoyan Zhang

Presentation of Science Writing Awards

Science Writing Award for Professionals in Acoustics
Diana Deutsch, for "Speaking in Tone" published in *Scientific American Mind*, July 2010

Science Writing Award in Acoustics for Journalists
Christopher Bauer, Lindsay Kelliher, Amy Miller, Linda Peckham,
Paul Rogers for their Internet segment
"QUEST Lab: Speed of Sound" aired April 6, 2010

Announcement of the 2011 Munk Award granted jointly by
The Oceanography Society, the Office of Naval Research,
and the Office of the Oceanographer of the Navy

Presentation of Acoustical Society Awards

Rossing Prize in Acoustics Education to Robert C. Coffeen

Distinguished Service Citation to Uwe J. Hansen

Distinguished Service Citation to Richard Stern

Silver Medal in Signal Processing in Acoustics to Theodore G. Birdsall

Trent-Crede Medal to Peter R. Stepanishen

Wallace Clement Sabine Award to J. Christopher Jaffe

Session 3eED

Education in Acoustics and Committee on Women in Acoustics: Listen Up and Get Involved

Marcia J. Isakson, Cochair
Applied Research Lab., Univ. of Texas, 10000 Burnet Rd., Austin, TX 78713

Tracianne B. Neilsen, Cochair
Dept. of Physics and Astronomy, Brigham Young Univ., N283 Eyring Science Center, Provo, UT 84602

Invited Papers

3eED1. Who is an Acoustician? Wendy K. Adams (Dept. of Phys., Univ. of Northern Colorado, CB 127, Greeley, CO 80639)

The "traveling road show" originally put together by ASAs own Uwe Hansen includes a range of hands-on demonstrations of physical phenomena such as standing waves & resonance, energy carried by sound, and spectrum analysis just to name a few. This show is presented to Girl Scouts with the goal of exciting young ladies about science and letting them interact with female scientists. To further this goal, I propose creating a station that describes careers of acousticians in the various technical areas to educate the young ladies about what different acousticians do in their day to day activities. Career profiles that were previously created for the exploresound.org website will be used along with information presented in a fun, straightforward, graphical, easy to read poster presentation.

3eED2. The sound of resonance. Katherine Hart and Tracianne B. Neilsen (Dept. of Phys. and Astronomy, Brigham Young Univ., N283 ESC, Provo, UT 84602)

A basic understanding of the production of sound waves can be obtained by studying standing waves and resonance frequencies. A vibrating string will settle into a steady, standing wave pattern when it is driven at one of its resonance frequencies. The resonance frequencies depend on the string's length and the tension applied to the string. Similarly the resonance frequencies of tubes are determined by the tube's length and whether the ends are open or closed. In a series of hands-on demos, we will explore the factors that influence the creation of standing waves by exciting the resonances of strings, tubes, rods, a metal plate, slinky, and a wine glass. These simple models provide insight into how musical instruments produce sound.

3eED3. Do you hear what I hear? Tracianne B. Neilsen (Dept. of Phys. and Astronomy, Brigham Young Univ., N283 ESC, Provo, UT 84602)

Have you ever wondered if the person next to you hears the same thing you hear? It depends. The response of our ears varies significantly with age because a person's cumulative exposure to noise lessens their ears' ability to respond to sounds. This common form of hearing loss is called presbycusis and is characterized by a significant degradation in the high frequency content of the perceived sound. A series of auditory demonstrations distributed by the Acoustical Testing Center at NASA Glenn Research Center lets you hear what a person with progressively worse presbycusis hears.

3eED4. The influence of noise on speech intelligibility. Hillary Jones and Tracianne B. Neilsen (Dept. of Phys. and Astronomy, Brigham Young Univ., N283 ESC, Provo, UT 84602)

When you are listening to speech, a lecture, or a performance, the sound waves travel through the room to reach you. Along the way, the speech sounds interfere with the other sounds in the room such that the sound reaching your ears is often corrupted by noise. The addition of noise decreases the intelligibility of the speech. A series of auditory demonstrations distributed by the Acoustical Testing Center at NASA Glenn Research Center let you hear how the speech intelligibility decreases as the amount of external and internal noise in a lecture hall, classroom, or workplace increases.

3eED5. Scripps classroom connection NSF Graduate STEM Fellows in K-12 education program. Brianne Moskovitz (Marine Physical Lab., Scripps Inst. of Oceanogr., 291 Rosecrans St., Bldg. 4, San Diego, CA 92106, bmoskovi@ucsd.edu), Hubert Staudigel, and Cheryl Peach (Scripps Inst. of Oceanogr., San Diego, CA 92037)

The scripps classroom connection (SCC) graduate STEM fellows in K-12 Education is a 5-yr program funded through NSF's Division of Graduate Education. The goal of this program is to prepare graduate students for professional and scientific careers for the 21st century. In addition to improving communication and presentation skills for the graduate fellows, the program brings authentic science into middle and high school classrooms of the San Diego Unified School District and creates an enduring set of lesson plans and activities based on the interdisciplinary science conducted at Scripps. One such lesson involves the introduction to ocean acoustics. An activity to accompany this lesson shows the difference in comparison of how sound travels in air and how sound travels in water. Students are able to understand that acoustic waves travel differently in different media.

3eED6. Hands-on demonstrations for Project Listen Up: Education outreach part III. Amie E. Nardini, Jacqueline Blackburn, and Murray S. Korman (Phys. Dept., U.S. Naval Acad., Annapolis, MA 21402)

Midshipmen will be getting involved in an ASA education outreach effort by presenting or recording a number of acoustical demonstrations geared to promote a hands-on learning experience for middle- and high-school age girl scouts. This is an extension of the demonstration effort and outreach presented at the ASA Meeting held in Baltimore in 2009 and Seattle in 2011. The demos are designed to visualize certain wave effects that will be explained by the Midshipmen "live" or by computer video. The participants will be free to explore, control the apparatus, and make their own scientific discoveries. The hands-on demonstrations will include (1) a ripple tank with two separated periodic point sources or a plane wave source driver for wave studies, (2) an ultrasonic motion sensor for measuring and displaying displacement, particle velocity and acceleration of an oscillating object or a person's motion, (3) tuning forks matched to Helmholtz resonators, and (4) a driven clamped circular plate supporting a column of dry sifted masonry sand (or uncooked rice or grass seed) for studying the resonant frequency versus. granular mass loading.

WEDNESDAY EVENING, 2 NOVEMBER 2011 SUNRISE, 7:00 TO 9:00 P.M.

An Evening to Remember with the Hutchins Consort

Thomas D. Rossing, Master of Ceremonies
Stanford University, Stanford, CA 94305

The Hutchins Consort plays on the eight-scaled violins of the violin octet designed and built by famed luthier Carleen Hutchins. The instruments are the first successful attempt to create an acoustically balanced set of instruments that can sound truly like violins across the entire range of written music. The Hutchins Consort plays music of the Middle Ages and Renaissance to the music of the modern masters. With original compositions and transcriptions commissioned by the Catgut Acoustical Society for the octet of violins, and new transcriptions by members of the Consort, The Hutchins Consort displays a breadth and depth that few traditional groups match, and a sound that is truly unique.

WEDNESDAY EVENING, 2 NOVEMBER 2011 7:30 TO 9:30 P.M.

OPEN MEETINGS OF TECHNICAL COMMITTEES

The Technical Committees of the Acoustical Society of America will hold open meetings on Tuesday, Wednesday, and Thursday evenings beginning at 7:30 p.m.

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

Committees meeting on Wednesday are as follows:

Biomedical Acoustics	Royal Palm 5/6
Signal Processing in Acoustics	Royal Palm 1/2