Session 1aAA

Architectural Acoustics and Education in Acoustics: Computer Modeling in Buildings and the Environment as an Education Tool

Norman H. Philipp, Cochair
Geiler and Associates, LLC, 1840 E. 153rd Cir., Olathe, KS 66062

Ronald Sauro, Cochair
NWAA Labs, Inc, 90 Tower Blvd., Elma, WA 98541

Chair's Introduction—9:00

Invited Papers

9:05

1aAA1. Using computer building modeling and auralization as teaching tools. Robert C. Coffeen (School of Architecture, Design & Planning, Universtiy of Kansas, 1465 Jayhawk Blvd, Lawrence, KS 66045, coffeen@ku.edu)

Acoustic building modeling in computer programs is very useful in the understanding of room acoustics for venues of various types by architecture and architectural engineering students. Models provide calculation of reverberation time using the Sabine and similar equations as interior materials are changed. Ray tracing can be used to understand the effect of disturbing sound reflections from interior surface shapes and locations. Being able to create impulse responses in a model allows the estimation of reverberation time using Schroeder integration. And, transferring impulse responses to a measurement and analysis program allows determination of early decay time as well as T10, T20, T30 and other sound decay cutoff times. In addition, more advanced students can determine Sound Transmission Class STI, Strength G, Inter-aural Cross Correlation Coefficient IACC, and other acoustic parameters. But, one of the most useful items that can be produced by model impulse responses is auralization. This allows students to hear a simulation of room sound as reverberation time and other acoustic parameters are changed. Examples of using one of the several modeling and analysis programs will be presented.

9:25

1aAA2. Simple interactive virtual auralizations as educational tools. Christopher L. Barnobi (Stewart Acoustical Consultants, 7330 Chapel Hill Rd, Suite 101, Raleigh, NC 27607, chris@sacnc.com)

This presentation provides an overview and demonstration of some 'classic' acoustic phenomena using a computer simulation. The computer program provides a visual rendering of an environment with a source and receiver. By allowing the user to vary some of the parameters of the environment, a user can see and hear the differences in spaces by changing the surroundings. The goal is to highlight the well known environmental factors that impact sound such as volume in a room. A variety of parameters and environments will be explored.

9:45

1aAA3. Education technology in architectural acoustics: A hands-on program for teaching. Norman H. Philipp (School of Architecture, Design & Planning, University of Kansas, Lawrence, KS 66045, philipp.norman@gmail.com)

Through the implementation of educational technology a web-based educational tool is being developed to aide in the teaching of architectural acoustics to architecture students at the undergraduate and graduate level. As the first step, its scope has been limited to reverberation time in architectural acoustics. The overall objective is to provide a dynamic educational tool for both educators and students to improve their understanding and retention of the principles of architectural acoustics.

10:05–10:25 Break

10:25

1aAA4. Finite difference simulation methods as an educational tool. Jonathan Botts, Ning Xiang, and Todd Brooks (Graduate Program in Architectural Acoustics, Rensselaer Polytechnic Institute, 110 8th St., Greene Building, Troy, NY 12180, botts.jonathan@gmail.com)

Finite difference methods can be a valuable and unexpected tool in acoustics education. As a wave acoustic simulation method, it provides instructive time-domain visualizations particularly useful for illustrating broadband wave effects like diffraction and interference. Furthermore, the knowledge required to implement these simulations can be taught in just a few hours of instruction with or without calculus in contrast to several other wave acoustic methods. The exposition provides opportunities for discussion of basic numerical methods as well as the physics of wave and diffusion processes. We present example projects from students of mixed science, engineering, and music backgrounds. After only four hours of instruction, they were able to independently simulate various room geometries

with impedance boundary conditions along with a variety of other acoustical systems. Beyond strictly educational value, this is a flexible and free tool that the modern acoustician can use for research, physics-based simulation, or creation of broadband virtual sound fields.

10:45

1aAA5. Accuracy of acoustic simulations and the effects of material databases. Ronald Sauro (NWAA Labs, Inc, 90 Tower blvd, Elma, WA 98541, audio_ron@msn.com)

A discussion of the effects of material databases on the accuracy of predictions emanating from acoustic simulation programs. This brings to light the lack of inherent accuracy in these programs because of the lack of accuracy in the measurement of absorption, scattering and diffusion parameters. Some of the predictions can be shown to be off as much as 300 to 500 per cent. We look at possible corrections in these measurements and how they can improve these predictions.

Contributed Papers

11:05

1aAA6. Parallelized finite difference time domain room acoustic simulation. Cameron Fackler, Jonathan Botts, and Ning Xiang (Graduate Program in Architectural Acoustics, School of Architecture, Rensselaer Polytechnic Institute, 110 8th St, Greene Building, Troy, NY 12180, facklc@rpi.edu)

A parallelized room acoustics simulator based on the finite difference time domain (FDTD) method is developed, utilizing a Blue Gene/L supercomputer. Wave-based methods such as FDTD are desirable for use in room acoustics simulations since they account for effects such as diffraction and interference. However, such methods require large amounts of computational power and memory, especially when simulating large volumes or high frequencies. To utilize the power of modern computing systems and move toward large-scale simulations of realistic concert halls, a parallel FDTD implementation is written in the C++ programming language with the Message Passing Interface (MPI) library. The volume to be simulated is partitioned into blocks, which efficiently update shared interfaces between nearest neighbors using the Blue Gene architecture's point-to-point communication network. Several compact explicit FDTD schemes are compared using simulations of various spatial volumes, executed on varying numbers of processors. The use of a Blue Gene/L supercomputer demonstrates substantial speedup over an equivalent serial implementation.

11:20

1aAA7. Acoustic simulation of the church of San Francesco della Vigna. Braxton B. Boren (Music, New York University, New York, NY 10012, bbb259@nyu.edu) and Malcolm Longair (Cavendish Laboratory, University of Cambridge, Cambridge, Cambridgeshire, United Kingdom)

San Francesco della Vigna is the oldest church in Venice for which there is evidence that acoustic considerations were taken into account in the architectural design. Francesco Zorzi, a humanist scholar, recommended that the church have a flat wooden coffered ceiling to improve the intelligibility of the sermons preached there. But instead of Zorzi's recommended flat ceiling, the church was built with a plaster vault ceiling. Using measured acoustic data from the CAMERA project, a virtual model of the church was constructed in Odeon whose simulated parameters matched the measured values at different source-receiver combinations. After obtaining a good match to the measured values, this virtual model was then altered to reconstruct the flat ceiling recommended by Zorzi. This ceiling was then placed at the two different heights at which it might have been built in Zorzi's time. The simulations show that the more absorptive ceiling might have slightly reduced the long reverberation time in the church. However, the ceiling would have been too high to make any significant change in the D50, which still remains extremely low. Thus this simulation indicates that Zorzi's ceiling would not have made the impact on speech intelligibility he had expected.

Session 1aAO

Acoustical Oceanography and Underwater Acoustics: Memorial Session in Honor of Clarence S. Clay I

Dezhang Chu, Cochair
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John K. Horne, Cochair
School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA 98195

J. Michael Jech, Cochair
Northeast Fisheries Science Center, Woods Hole, MA 02543

Timothy K. Stanton, Cochair
Woods Hole Oceanographic Institution, Woods Hole, MA 02543-1053

Chair's Introduction—8:55

Invited Papers

9:00

1aAO1. C.S.Clay: A distinguished acoustician. Ivan Tolstoy (Knocktower, Knockvennie, Castle Douglas DG7 3PA, United Kingdom, tstanton@whoi.edu)

Clay's well-known work in ocean acoustics earned him an international reputation. His contributions ranged from studies of sound propagation in shallow water to the application of filter theory in noisy environments, diffraction from rough surfaces, sound scatter by fish and, generally speaking, the execution and design of numerous experiments. Less well known, perhaps on account of his modesty, was his role at Columbia University's Hudson labs in designing a fully digitized microphone array for the study of low frequency atmospheric waves (in the 1 to 600 sec. period band), which led to the detection of gravity and acoustic-gravity waves from several nuclear tests. After leaving Columbia, Clay accepted a professorship at the University of Wisconsin where, among other things, he taught geophysics and continued research on sound scatter. His presence and participation at Acoustical Society meetings will be sorely missed.

9:20

1aAO2. C.S. Clay—A scientist of outstanding vision, brilliance, and versatility. Christopher Feuillade (Facultad de Física, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Santiago, Región Metropolitana, Chile, chris.feuillade@gmail.com)

During a scientific career of more that 60 years, Clarence Clay made many important research contributions spanning a wide range of topics in ocean acoustics, acoustical oceanography, geophysical exploration, signal processing, SONAR system applications and techniques, and more. His achievements are detailed in over 135 peer-reviewed articles, abstracts, technical reports, and at least five patents. In addition he was the author, or co-author, of four widely read textbooks. His research work is recognized internationally for the far-reaching significance of many of the advances he made. In order to attempt a proper appreciation of the range and versatility of Clay's accomplishments, within the constraints of a 30 minute presentation, this talk will consist of a series of brief overviews of a representative selection of topics on which he worked. These include: the theory and measurement of rough surface scattering, particularly at the ocean boundaries; matched-filter signal transmission and detection, time reversal, and matched-field processing; acoustic methods and models for scattering from individual fish, and for fish detection and abundance estimation; the theory and experimental investigation of time domain scattering from wedges, and its incorporation into wedge assemblage models; and the theory and applications of seismic exploration and profiling.

9:50

1aAO3. A review of Clarence Clay's research contributions in the area of fisheries acoustics. John Ehrenberg (Hydroacoustic Technology Inc, 715 NE Northlake Way, Seattle, WA 98105, jehrenberg@htisonar.com)

This presentation provides an overview of the significant contribution that Clay and his students made to the understanding of the statistical nature of the acoustic signals scattered from fish and the methods for removing the effect of the beam pattern from the received echo statistics to measure the underlying fish backscattering statistics. By making measurements of the acoustic scattering from live fish, he showed that the probability density function of the envelope amplitude of the echo signal scattered from the fish could be modeled by a Ricean PDF. He further showed that as the ratio of the length of the fish to the acoustic wavelength became large, the PDF became Rayleigh distributed. Clay and his students were interested in using the measured echo statistics to obtain information about the size distribution of the fish producing the scattering. They developed a method for deconvolving the effect of the acoustic beam pattern from the received echo statistics to provide an estimate of the fish scattering PDF. The effectiveness of the technique was demonstrated for a fish population in a Wisconsin lake.

10:10–10:25 Break

10:25

1aAO4. Estimating numerical density of scatterers in monotype aggregations using the statistics of broadband echoes: Applications to fish echoes. Wu-Jung Lee, Timothy K. Stanton, and Andone C. Lavery (Department of Applied Ocean Physics and Engineering, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, wjlee@whoi.edu)

The statistics of echoes from active sonar systems can yield important information on aggregations of scatterers. This study explores the use of echo statistics for estimating the numerical density of scatterers in monotype aggregations. Here, "monotype" refers to scatterers with the same scattering amplitude distribution in the considered frequency range. The signals are broadband, and the geometry involves direct paths between the sonar and the scatterers without interference from boundaries. Model probability density functions (pdf's) of envelope amplitudes of matched-filter outputs are numerically generated by varying the number of Rayleigh scatterers randomly-distributed in a half-space shell while accounting for the frequency-dependent system response, scatterer response, and beampattern effects. The shape of the echo pdf as observed by the sonar receiver is highly non-Rayleigh when there are few scatterers in the beam, and gradually approaches the Rayleigh distribution when the number of scatterers increases. This model is applied to broadband fish echoes (30-70 kHz) collected in the ocean through a best-fit procedure. The inferred numerical density of fish is comparable to the density estimated using corresponding measurements of volume backscattering strength and modeled target strengths.

10:40

1aAO5. Ice cream and the application of backscatter models. John K. Horne (School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195, jhorne@u.washington.edu)

I was invited to visit Clay and colleagues at the Center for Limnology at the University of Wisconsin, Madison in October 1991. As an acoustics neophyte, I had lots of questions that Clay patiently took the time to answer while we ate ice cream at the Memorial Union. That discussion led to the development of the Kirchhoff Ray-mode (KRM) model and increased the use of acoustic scattering models to investigate how fish reflect sound. Acoustic scattering models enable investigation of factors or conditions that cannot be replicated or isolated in field or experimental measures. The iterative combination of models with measures improves accuracy of model predictions and the understanding of how the physics of sound interacts with biology to produce acoustic data. Both the structure and application of backscatter models have evolved in their complexity and realism. Examples will be used to illustrate advances in and insight gained through modeling, with special consideration of Clay's contributions. The talk will conclude with speculation on what Clay would see as the next step.

10:55

1aAO6. Low frequency acoustical scattering properties of large schools of swim bladder fish. María P. Raveau (Facultad de Ingeniería, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Región Metropolitana, Chile) and Christopher Feuillade (Facultad de Física, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Santiago, Chile, chris.feuillade@gmail.com)

The collective back scattering behavior of fish schools has previously been described by a school scattering model [J. Acoust. Soc. Am., **99**(1), 196-208 (1996)], which incorporates both multiple scattering effects between neighboring fish, and coherent interactions of their individual scattered fields. In the present work, the school scattering model has been extended, and used to investigate the back- and forward-scattering properties of the acoustic field, and transmission through, large schools of swim bladder fish, at frequencies close to the swim bladder resonance frequency. Results show that their frequency and spatially-varying scattering behavior depends strongly upon the number of fish in the school ensemble, the species specific swim bladder size, the average spacing between fish, and the size and shape of the school. Results will also be presented of a comparison between the school model and fish absorption data obtained during the experiment Modal Lion, performed in the Gulf of Lion in September 1995, and reported by Diachok [J. Acoust. Soc. Am., **105**(4), 2107-2128 (1999)]. [Work supported by ONR.]

11:10

1aAO7. Acoustic characterization of thecosome pteropods and recent field measurements in the context of ocean acidification. Andone C. Lavery (Applied Ocean Physics and Engineering, Woods Hole Oceanographic Institution, 98 Water Street, MS 11, Bigelow 211, Woods Hole, MA 02543, alavery@whoi.edu), Gareth L. Lawson, Peter H. Wiebe (Biology, Woods Hole Oceanographic Institution, Woods Hole, MA), Timothy K. Stanton, Jonathan R. Fincke (Applied Ocean Physics and Engineering, Woods Hole Oceanographic Institution, Woods Hole, MA), and Nancy J. Copley (Biology, Woods Hole Oceanographic Institution, Woods Hole, MA)

One of Clay's passions was modeling the scattering physics of marine organisms, a passion that has transcended into new generations of scientists. The focus of this presentation is thecosome pteropods, a widely and patchily distributed group of shelled zooplankton that are important members of pelagic ecosystems as they constitute important prey for a variety of other zooplankton and top predators. Acoustic techniques are well suited to sampling pteropods on relevant spatial and temporal scales as they secrete aragonite shells that make them highly efficient scatterers of sound. However, pteropod shells are complex and very susceptible to an increasingly corrosive seawater environment due to ocean acidification. Understanding the scattering physics is key to using acoustics as a quantitative remote sensing tool. Here we report on recent field measurements that combine the use of broadband (30-600 kHz) and narrowband (43, 120, 200, and 420 kHz) acoustic scattering techniques, as well as supporting in situ measurements (nets, optics, CTD and ocean chemistry) to investigate the distribution, abundance and size of pteropods in both the northwest Atlantic and the northeast Pacific in relation to the oceanic chemistry. Existing scattering models are tested, and improvements and modifications to the acoustic instrumentation and models are suggested.

11:25

1aAO8. Echo statistics: Pursuing one of Clay's visions. Timothy K. Stanton (Dept. of Applied Ocean Physics and Engineering, Woods Hole Oceanographic Institution, MS #11, Woods Hole, MA 02543-1053, tstanton@whoi.edu) and Dezhang Chu (National Marine Fisheries Service - Northeast, National Oceanic and Atmospheric Administration, Seattle, WA)

One of the first papers that Clay gave to one of the authors (TKS) when he entered Clay's office in 1980 was one of Clay's papers involving echo statistics and, specifically, accounting for beampattern effects in using single beam echoes from resolved fish to estimate their target strength and abundance. That, and a multitude of conversations with Clay helped propel TKS, and later DC, into a career where echo statistics was an integral aspect of their work. We will review our work on echo statistics associated with a variety of scatterers–the seafloor, sea ice, fish, zooplankton, and machined objects. A key aspect of this work has been connecting the physics of the scattering process and sonar parameters with parameters of the statistical functions (such as shape parameter).

11:40–12:00 Panel Discussion

Session 1aEA

Engineering Acoustics, Signal Processing in Acoustics, and Animal Bioacoustics: Broadband, Complex Pulses for Echolocation

Kenneth M. Walsh, Chair
K+M Engineering Ltd, 51 Bayberry Ln., Middletown, RI 02842

Chair's Introduction—8:25

Invited Papers

8:30

1aEA1. Broadband synthetic aperture chirp reflection profiling. Steven Schock (Ocean and Mechanical Engineering, Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431, sschock@fau.edu), Jason Sara (Edgetech, Boca Raton, FL), and Kenneth M. Walsh (K M Engineering Ltd., Middletown, RI)

A newly developed towed chirp subbottom profiler transmits FM pulses with a bandwidth of three octaves to generate high resolution reflection profiles of the seabed. The broad bandwidth of the pulses, generated with two arrays of piston sources, produces the temporal resolution needed for resolving fine sediment layering. A 40 channel horizontal hydrophone array, embedded in vehicle wings, provides the acoustic aperture for enhancing the across track resolution of subsurface features and reducing sediment scattering noise. After application of a matched filter, synthetic aperture processing of hydrophone data generates a large aperture along the track of the sonar vehicle thereby improving along track image resolution and obtaining a further reduction in scattering noise. The reductions in backscattering from sediments yield imagery with improved subsurface penetration. The reflection profiles are stacked envelopes of coherently summed data formed by time domain focusing on planar surfaces oriented over a range of discrete slopes. This work was funded by the National Science Foundation.

8:55

1aEA2. Odontocete biosonar signals: Functional anatomy or signal design. Whitlow W. Au (HI Institute of Marine Biology, University of Hawaii, 46-007 Lilipuna Road, Kaneohe, HI 96744, wau@hawaii.edu)

There are between 67 and 76 species of odontocetes (toothed whales) and presumably all have biosonar capabilites. There are three fundamental biosonar signal types that can be categorized by types of marine mammals that produce these signals. Whales and dolphins that can emit whistle signals (except for sperm whales) project short broadband clicks containing about 5 to 7 cycles with decaying exponential envelope and Q (center frequency over bandwidth) between 2 and 3. Porpoises do not whistle and produce polycyclic narrow band high frequency biosonar signals with approximately 20 or more cycles with a modified sinusoidal amplitude envelope and Q around 14. Biosonar waveforms of beaked whales (also non-whistling animals) typically have 10-15 cycles with a linear FM component and Q around 4. This presentation will discuss the characteristics of the three different biosonar signal types and suggest some motivation factors involved with the use of the different signals. The type of prey and their habitat will also be included in the discussion. It will be shown that in some cases, the signal type is motivated by anatomical constraints of the odontocete and in other cases, the backscatter characteristics of the prey may be the most important factor.

9:20

1aEA3. Implications of the variety of bat echolocation sounds for understanding biosonar processing. James A. Simmons (Neuroscience, Brown University, 185 Meeting St., Box GL-N, Providence, RI 02912, james_simmons@brown.edu), Matthias Hoffmann-Kuhnt, Tzi Ming Leong (National University of Singapore, Singapore), Shizuko Hiryu, Hiroshi Riquimaroux (Doshisha University, Kyotanabe, Kyoto, Japan), Jeffrey M. Knowles (Neuroscience, Brown University, Providence, RI), and Cynthia F. Moss (University of Maryland, College Park, MD)

The variety of echolocation sounds used by different species of bats have implications for target ranging. Signals recorded at individual sites reveal species stacked in different frequency bands, perhaps to avoid cross-interference. Search-stage signals include short single-harmonic or multi-harmonic tone-bursts, or very shallow FM bursts. These narrowband sounds have abrupt onsets to evoke phasic on-responses that register echo delay, but with limited acuity. Wider FM sweeps used for searching by other bats evoke on-responses at many more frequencies for better delay acuity. These sound types may signify foraging in the open, within broad spaces bounded relatively remotely by trees or the ground. Intervals between broadcasts are consistent with biosonar operating ranges set by the boundaries of the scene in relation to atmospheric attenuation. Most species make transitions to wider signal bandwidth during interception by increasing FM sweep-width or adding harmonics. Additionally, wideband, multi-harmonic FM sounds are used by species that frequently fly vegetation; they use harmonic processing to suppress surrounding clutter and perceive the path to the front. These observations suggest basic echo-delay processing to determine target range, with increasing bandwidth first to improve delay acuity and then to determine target shape. [Work supported by ONR and NSF.]

9:45

1aEA4. Dolphins use "packets" of broadband clicks during long range echolocation tasks. James J. Finneran (US Navy Marine Mammal Program, SSC Pacific Code 71510, 53560 Hull St., San Diego, CA 92152, james.finneran@navy.mil)

When echolocating, dolphins typically emit a single short duration, high-frequency, broadband "click," then wait for the echo to return before emitting another click. However, previous studies have shown that dolphins and belugas performing long-range echolocation tasks may instead emit a burst, or "packet," of several clicks, then wait for the packet of echoes to return before emitting another packet of clicks. The exact reasons for the use of packets, rather than individual clicks, is unknown. In this study, the use of packets by dolphins was examined by having trained bottlenose dolphins perform long-range echolocation tasks. The tasks featured the use of "phantom" echoes produced by capturing the dolphin's outgoing echolocation clicks, convolving the clicks with the impulse response of a physical target to create an echo waveform, then broadcasting the delayed, scaled echo waveform back to the dolphin. Dolphins were trained to report the presence of phantom echoes or a change in phantom echoes. At ranges below 75 m, the dolphins rarely used packets of clicks. For ranges greater than 75 m, the likelihood of packet use was related to both target range and echo strength. [Work supported by the SSC Pacific Naval Innovative Science and Engineering (NISE) program.]

10:10–10:25 Break

10:25

1aEA5. Environmentally neutral complex broadband biomimetic waveforms for active sonar. Peter F. Dobbins (Advanced Systems, Ultra Electronics Sonar Systems, Waverley House, Hampshire Road, Weymouth, Dorset DT4 9XD, United Kingdom, peter.dobbins@ultra-sonar.com)

There is an expanding requirement to reduce the impact of man-made sound, including active sonar transmissions, on marine mammals in the defence, offshore and other sectors. This is driven partly by increased public interest in these animals, but mainly by legislation such as the US Marine Mammal Protection Act, and similar regulatory and licensing requirements throughout the world. Typically, such requirements are met using monitoring by Marine Mammal Observers or Passive Acoustic Monitoring. Having detected animals within a specified range, some form of mitigating action such as shutting down the sound source is then necessary. However, in general it is difficult to ensure the absence of marine mammals before transmitting, so it is desirable to look for forms of sonar waveform that are potentially less harmful to marine life. One way this might be achieved is to use signals derived from natural sounds such as the vocalisations of the animals themselves. It might be expected that such sounds would appear more familiar, thus reducing possible abnormal behavioural impacts. This paper reviews the use of such waveforms and presents a preliminary estimate of their performance in practical sonar systems, along with an assessment of the potential impacts on marine life.

10:50

1aEA6. Measuring the covertness of broadband sonar waveforms. Joonho D. Park and John F. Doherty (Electrical Engineering, Pennsylvania State University, State College, PA 16802, jdp971@psu.edu)

In underwater environment, the platform uses active sonar to estimate the range to the target, covertly. The target employs detectors designed to find anomalies in its ambient environment, including man-made waveforms such as ones transmitted by the platform. However, the structure of the waveform is unknown. In this scenario, we try to measure the covertness of the waveforms transmitted by the platform in various scenarios using a quantity related to relative entropy, and the performance of range estimation using the covert waveform. At the target, we measure the maximum probability of detection of the sonar waveform, for a specified false alarm rate. At the platform, we measure the probability of estimating the range to the target correctly. The performances of both processes are dependent on the amount of information one has about the ambient environment, the structure of the transmitted waveform, and the actual range between the platform and the target. We show how the performances are dependent on the accuracy of the knowledge about these elements.

11:15

1aEA7. Considerations in designing piezocomposite transducers and arrays for broadband sonar systems. Barry Doust, Tim Mudarri, Connie Ursch, Joe Aghia, and Brian Pazol (Electroacoustics, Materials Systems Inc., 543 Great Rd., Littleton, MA 01460, bdoust@matsysinc.com)

The term broadband is commonly used to refer to the capability of a sonar system. Recent advances in signal processing and system electronics have re-defined capabilities for these systems and introduced new complex broadband pulse requirements for the sonar transducer. Advances in 1-3 piezocomposite technology have addressed this need through optimization of materials and innovative electroacoustic designs to provide high performance broadband solutions. Taking full advantage of this transducer technology requires careful consideration of the total system performance including dynamic range of receiver electronics, available transmit voltage/current/power, directivity and array configuration. This generalized study considers the design options available for optimizing transducers and arrays for broadband operation. Several Langevin or sandwich style Piezocomposite transducer configurations will be presented for both monostatic (two-way) and bistatic (separate receive and transmit) transducer systems and the trades in terms of total system performance. The study includes comparison of design optimization methodologies based on peak frequency response, impedance phase center or maximum transmit power factor, and combined two way system response. Emphasis will be on conventional piezoceramic materials with some discussion of second generation single crystal materials and their potential in future systems.

Contributed Paper

11:40

1aEA8. A generalized sinusoidal frequency modulated waveform for active sonar. David A. Hague and John R. Buck (Electrical and Computer Engineering, University of Massachusetts Dartmouth, North Dartmouth, MA 02747, david.a.hague@gmail.com)

Pulse-Compression or Frequency Modulated (FM) active sonar waveforms provide a significant improvement in range resolution and reverberation suppression over Continuous Wave (CW) waveforms. The Sinusoidal FM (SFM) waveform modulates its instantaneous frequency (IF) by a sinusoid to achieve high Doppler sensitivity while maintaining desirable reverberation suppression. This allows the SFM waveform to resolve target velocities much better than the Doppler tolerant Hyperbolic FM waveform. However, the SFM suffers from poor range resolution as the Auto-Correlation Function (ACF) contains many ambiguous peaks generated by the periodicity of the SFM's IF. The periodic sidelobes in the ACF for the SFM signal are similar to those exhibited by periodic CW waveforms, which motivated the development of FM waveforms to improve range resolution. This suggests that modifying the SFM waveform to use an aperiodic modulating function should improve range resolution while preserving Doppler sensitivity. This talk presents an active sonar waveform where the IF function is itself an FM chirp waveform, and for which the SFM is a special case. This generalized sinusoidal FM waveform resolves target range and velocity with reverberation suppression comparable to other well-established FM waveforms. [Work supported by ONR and the SMART Program.]

MONDAY MORNING, 22 OCTOBER 2012 — ANDY KIRK A/B, 10:00 A.M. TO 12:00 NOON

Session 1aMU

Musical Acoustics: General Topics in Musical Acoustics

Thomas R. Moore, Chair
Department of Physics, Rollins College, Winter Park, FL 32789

Contributed Papers

10:00

1aMU1. Choir hearing responses: Rehearsal versus performance configurations. Glenn E. Sweitzer (Sweitzer LLP, 4504 N Hereford Dr, Muncie, IN 47304, glenn.sweitzer@gmail.com)

Choir member responses to hearing (sung parts) in a rehearsal room are compared with those for its associated performance stage. Anonymous scaled responses from each choir member are gathered simultaneously using a personal response system. The protocol is repeated in a rehearsal room for the choir voices configured by 1) part versus mixed; and 2) on risers versus flat floor. On the performance stage, the protocol is repeated for same. Prior to each set of responses, the choir sings a prayer familiar to the choir members. The responses vary widely between rehearsal and performance venues, and by configuration in each. These findings suggest that choir member response may be largely ignored in the design and operation of choir rehearsal and performance facilities. Potentials for improving choir member hearing in existing rehearsal and performance venues is discussed.

10:15

1aMU2. The origins of longitudinal waves in piano strings. Brandon August, Nikki Etchenique, and Thomas R. Moore (Department of Physics, Rollins College, 1000 Holt Ave., Winter Park, FL 32789, tmoore@rollins.edu)

The importance of longitudinal waves in piano strings has been previously identified by several investigators. Recent experimental work has provided insight into the origin of these waves and their relationship to the transverse string motion. These measurements indicate that there are multiple regimes in which longitudinal waves are created through different processes.

10:30

1aMU3. Automatic transcription of monophonic piano music. Fatemeh Pishdadian and Jill K. Nelson (Electrical and Computer Engineering, George Mason University, 4400 University Drive, ECE Department, Volgenau School of Engineering, Fairfax, VA 22030-4444, fpishdad@masonlive.gmu.edu)

Automatic music transcription refers to the process of transforming an acoustic musical signal into a written symbolic representation, e.g. a score. This process consists of extracting the parameters of note events, for instance pitches, onset times, and durations, from a raw acoustic signal. We have developed a novel algorithm for transcription of monophonic piano music, which addresses the challenges of pitch and note sequence detection in two stages: (1) The K-Nearest Neighbor (KNN) classification method is employed to identify K pitch candidates, based on spectral information, for each note event. (2) The most likely note sequence is determined by running a best-first tree search over the note candidates based on both spectral information and note transition probability distributions. The proposed two-step approach provides the performance gain achieved by incorporating note transition probabilities while maintaining significantly lower computational complexity than existing support vector machine and hidden Markov model methods. The algorithm was evaluated on a database comprised of excerpts from Bach's inventions. By performing a low complexity tree search based on note transition information, we achieve approximately 10% improvement over using only spectral information, correctly classifying roughly 85% of the notes in the database.

10:45

1aMU4. Multiple-timbre fundamental frequency tracking using an instrument spectrum library. Mert Bay and James W. Beauchamp (Electrical & Computer Engineering, University of Illinois at Urbana-Champaign, Champaign, IL 61820, mertbay@illinois.edu)

Recently many researchers have attempted automatic pitch estimation of polyphonic music (e.g., Li et al., IEEE Trans ASLP, 2009). Most of these attempts have concerned themselves with the estimation of individual pitches (F0s) while not associating the estimated pitches with the particular instruments that produce them. Estimating pitches for each instrument will lead to full music transcription. Individual instrument F0 tracks can be used in music information retrieval systems to better organize and search music. We propose a method to estimate the F0 tracks for a set of harmonic instruments in a sound mixture, using probabilistic latent component analysis (PLCA) and collections of basis spectra indexed by F0 and instrument learned in advance. The PLCA model is extended hierarchically to explain the observed input mixture spectra as a sum of basis spectra from note(s) of various instruments. The polyphonic pitch tracking problem is posed as inferring the most likely combination of the active note(s) from different instruments. Continuity and sparsity constraints are enforced to better model how the music is produced. The method was trained on a common instrument spectrum library an evaluated using an established polyphonic audio dataset.

11:00

1aMU5. Absolute pitch is associated with a large auditory digit span: A clue to its genesis. Diana Deutsch and Kevin Dooley (Department of Psychology, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0109, ddeutsch@ucsd.edu)

Absolute pitch (AP) is very rare in North America and Europe, and its genesis is unclear. Its prevalence is far higher among tone language speakers, and among those with early onset of musical training. However, most nontone language speakers with early and extensive musical training do not possess AP. To test the hypothesis that an unusually large auditory memory is involved in the genesis of AP, at least in nontone language speakers, we recruited 7 AP possessors, and 20 AP nonpossessors. All subjects were primary speakers of English, had begun musical training at $\leq$ age 6, and were UCSD students or recent graduates. The two groups were matched for age and years of musical experience. All subjects were administered an auditory digit span test, followed by a visual digit span test, with digits presented 1/sec. While the average auditory digit span was 8.1 digits for the AP nonpossessors, it was 10.0 digits for the AP possessors. This difference between the two groups was highly significant ($p = 0.0015$, 1-tailed). The AP possessors also marginally outperformed the nonpossessors on the visual digit span test; however this difference was nonsignificant. These new findings provide a clue to a genetic component of AP.

11:15

1aMU6. Perception of musical and lexical tones by musicians and nonmusicians. Chao-Yang Lee and Allison Lekich (Communication Sciences and Disorders, Ohio University, Grover W225, Athens, OH 45701, leec1@ohio.edu)

This study explores the relationship between musical and linguistic pitch perception. We asked whether the ability to identify musical tones is associated with the ability to identify lexical tones. English-speaking musicians and nonmusicians were asked to identify Taiwanese level tones produced by multiple speakers. Because pitch range varies across speakers and the tones were produced in isolation, participants had to estimate relative pitch height without cues typically available for speaker normalization. The musician participants were also asked to identify synthesized musical tones without a reference pitch. The results showed that both musicians and nonmusicians were able to identify Taiwanese tones above chance, but only for tones in the extremes of the speakers' overall pitch range. Preliminary data from the musicians show that musical tone identification accuracy was low and not associated with accuracy in the Taiwanese tone task. Implications of these findings for the music-speech relationship are discussed.

11:30

1aMU7. Measurement and analysis of timing asynchronies in ensemble performance. Gang Ren, Stephen Roessner, Samarth Hosakere Shivaswamy (Dept. of Electrical and Computer Engineering, Univ. of Rochester, Rochester, NY 14627, g.ren@rochester.edu), Dave Headlam, and Mark Bocko (Dept. of Electrical and Computer Engineering; Dept. of Music Theory, Eastman Sch. of Music, Univ. of Rochester, Rochester, NY)

Timing asynchrony is an important timing descriptor of ensemble music performance. In this paper the timing asynchrony is measured as offsets between "concurring" music onsets. Specifically we measure the offset between music note onsets that are prescribed to be synchronized according to the music score. First, we conduct measurements on the multi-track audio with separate instrument tracks. These multi-track materials are recorded by using acoustically isolated recording booth or by conducting multiple recording rounds. We then perform statistical analysis both on individual asynchrony points and on asynchrony points at key coordination locations, such as the start and the end of a music phrase. We emphasize in the analysis that the musical timing asynchronies should not be treated only as performance discrepancies because part of these micro-deviation patterns provide artistic "lively" elements. We also generalize the proposed framework to mixed-down polyphonic recordings. For polyphonic recordings where clear onsets can be identified we perform similar measurement and analysis algorithms as for separated multi-track recordings. For mixed-down polyphonic recordings where a clear separation of instrument tracks is not possible, we use onset dispersions, which measure the offset range of sonic partials onsets in an coordination points, as an alternative timing asynchrony descriptor.

11:45

1aMU8. The implementation of pyschoacoustical signal parameters in the wavelet domain. Matt Borland and Stephen Birkett (SYDE, University of Waterloo, 3-98 John St. W., Waterloo, ON N2L1C1, Canada, mjborlan@uwaterloo.ca)

Introducing Wavelet techniques into the psychoacoustical analysis of sound signals provides a powerful alternative to standard Fourier methods. In this paper the reformulation of existing psychoacoustical signal parameters using wavelet methods will be explored. A major motivation for this work is that traditional psychoacoustical signal analysis relies heavily on the Fourier transform to provide a frequency content representation of a time signal, but this frequency domain representation is not always accurate; especially for sounds with impactive components. These impactive events can have a more significant contribution to the calculation of psychoacoustical signal parameters by reformulating existing psychoacoustic parameters in the Wavelet domain that are dependent on the Fourier transform. To provide concrete examples of the results simulated "plucked string" sounds are analyzed with analogous Fourier and Wavelet domain signal parameters to demonstrate the difference in performance achieved using Wavelet methods for sounds which have impactive components.

Session 1aNS

Noise, Architectural Acoustics and Physical Acoustics: Sound Absorption of Micro-Perforated Structures

Li Cheng, Cochair
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Ning Xiang, Cochair
School of Architecture, Rensselaer Polytechnic Institute, Troy, NY 12180

Chair's Introduction—8:55

Invited Papers

9:00

1aNS1. On the use of micro-perforates for machinery and vehicle noise control. Mats Åbom and Sabry Allam (The Marcus Wallenberg Laboratory, KTH-The Royal Inst of Technology, Stockholm 10044, Sweden, matsabom@kth.se)

A micro-perforated plate (MPP) is a perforated plate with holes typically in the sub-millimeter range and perforation ratio around 1%. The values are typical for applications in air at standard temperature and pressure (STP). The underlying acoustic principle is simple: To create a surface with a built in damping that effectively dissipates sound waves. To achieve this, the specific acoustic impedance of a MPP is normally tuned to be of the order of the characteristic wave impedance in the medium (400 Pa*s/m in air at STP). The traditional application for MPP's has been building acoustics, normally in the form of a so called panel absorber to create an absorption peak at a selected frequency. However, MPP's made of metal are also well suited for machinery and vehicle noise control. For instance MPP's have the potential to be used instead of porous materials in dissipative mufflers, which not only can save weight but also offer a non-fibrous alternative. Furthermore, since MPP's have a large steady flow resistance they can be used as acoustically absorbing guide vanes at duct bends or as a fan housing. One important issue for these applications is the effect of flow on the MPP impedance. This issue plus a number of applications related to vehicle noise, have been studied at KTH during the last decade and this paper aims at summarizing the main results.

9:20

1aNS2. The effect of flexibility on the acoustical performance of microperforated materials. J. S. Bolton (Ray W. Herrick Laboratories, School of Mechanical Engineering, Purdue University, 140 S. Martin Jischke Drive, West Lafayette, IN 47907-2031, bolton@purdue.edu)

In conventional models of microperforated materials, the solid layer in which the holes are formed is usually considered to be rigid. However, microperforated materials are often thin, say less than 0.5 mm in thickness, and are sometimes made of lightweight polymeric materials. Experimental measurements suggest that when the mass per unit area of a microperforated material is less than approximately 0.5 kg per square meter, the motion of the solid layer becomes important. The solid layer is driven into motion both by the incident pressure acting on its surface and by viscous forces generated within the perforations. The ability of a microperforate to dissipate acoustical energy depends on there being relative motion between the air in the perforations and the solid layer: motion of the solid may either help or hurt this effect, particularly when the solid layer is supported on a grid-like structure, since the individual segments of the microperforate then exhibit modal behavior. In this presentation, models of this behavior will be described, and examples will be given in which essentially membrane-like behavior is modified by the presence of the perforations, and conversely, in which essentially rigid microperforated layer behavior is modified by vibration of the solid layer.

9:40

1aNS3. Micro-perforated elements in complex vibro-acoustic environment: Modelling and applications. Xiang Yu (Department of Mechanical Engineering, The Hong Kong Polytechnic University, Hong Kong SAR, China), Laurent Maxit, Jean-Louis Guyader (Laboratoire Vibrations Acoustique, Institut National des Sciences Appliquées (INSA) de Lyon, Lyon, France), and Li Cheng (Department of Mechanical Engineering, The Hong Kong Polytechnic University, FG611, Hung Hom, Kowloon, Hong Kong SAR 999077, China, mmlcheng@inet.polyu.edu.hk)

Micro-perforated structures/panels (MPP) are widely used in various architectural, industrial and environmental applications for providing efficient sound absorptions. More recently, they found their use in compact mechanical systems, in which the property of the MPP is shown to be strongly influenced by the surrounding vibro-acoustic environment, which is drastically different from the one dimensional Kundt tube configuration, usually used in existing works. Unfortunately, very little has been done in this regard, due to the fact that modeling such a vibro-coustic system with MPPs as integrative elements is a very challenging task, not even to mention the optimization. Recently, a vibro-acoustic formulation based on the Patch Transfer Function (PTF) approach was proposed to model micro-perforated structures in a complex vibro-acoustic environment. As a sub-structuring approach, PTF allows assembling different vibro-acoustic subsystems, including micro-perforations and the flexibility of a MPP, through coupled surfaces. The proposed

formulation provides explicit representation of the coupling among subsystems, with enhanced capability of handling system complexities and facilitating system optimization. In this talk, the overall approach will be reviewed and applied to a number of typical examples. The versatility and efficiency of the method as well as the underlying physics are demonstrated.

10:00–10:30 Break

10:30

1aNS4. A straightforward method toward efficient and precise impedance measurement for microperforation panels under flow conditions. Xiaodong Jing (School of Jet Propulsion, Beijing University of Aeronautics and Astronautics, No. 37, Xueyuan Road, Beijing 100191, China, jingxd@buaa.edu.cn)

This paper addresses the problem how to measure acoustic impedance of microperforation panels (MPPs) under flow conditions. Since 1960s, many different methods have been proposed to tackle this problem, mainly motivated by the aim of reducing noise emission from aeroengines, ventilators and other fluid machines. It has been found that the presence of flow favorably enhances the damping of MPPs due to the mechanism of sound-vortex interaction. This, however, leads to flow-dependent acoustic impedance whose determination is rather difficult. Despite considerable efforts over the past decades, there is still stringent need for developing efficient and precise impedance measurement method under flow conditions in order to fully explore the potentials of MPPs. Towards this goal, a straightforward method has been put forward to measure the acoustic impedance of an MPP lined in a flow duct (JASA, 124(1), 227-234). The basic principle is that the dominate axial wavenumber is extracted from the measured wall sound pressure by means of Prony method, thereby the unknown acoustic impedance is algebraically solved from the dispersion equation. In this paper, the straightforward method is further extended to incorporate the effects of flow boundary layer and higher-order acoustic modes that are essentially important for practical applications.

10:50

1aNS5. Hybrid silencer by using micro-perforated plate with side-branch cavities. Xiaonan Wang, Yatsze Choy, and Li Cheng (Department of Mechanical Engineering, The Hong Kong Polytechnic University, Hong Kong 852, mmyschoy@polyu.edu.hk)

A plate silencer consists of an expansion chamber with two side-branch cavities covered by light but extremely stiff plates. It works effectively with wide stopband from low-to-medium frequencies only if the plate is extremely stiff, to ensure a strong reflection of acoustic wave to the upstream in the duct. However, a plate with slightly weak bending stiffness will result in non-uniform transmission loss (TL) spectra with narrowed stopband. In this study, a hybrid silencer is proposed by introducing micro-perforations into the plate to elicit the sound absorption in order to compensate for the deficiency in the passband caused by the insufficient sound reflection in certain frequency range due to plate with weaker stiffness. A theoretical model, capable of dealing with the strong coupling between the vibrating micro-perforated plate and sound fields inside the cavity and the duct, is developed. Through a proper balancing between the sound absorption and reflection, the proposed hybrid plate silencer with moderately stiff plates is shown to outperform the typical plate silencer with very stiff plate. Whilst releasing the harsh requirement on the bending stiffness of the plate, the proposed hybrid silencer provides a more flattened and uniform TL and a widened stopband by about 30%.

Session 1aPA

Physical Acoustics, Architectural Acoustics, and Noise: Recent Developments in Computational Acoustics for Complex Indoor and Outdoor Spaces

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Computer Science, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3175

Chair's Introduction—8:00

Invited Papers

8:05

1aPA1. Modeling reflections from rough surfaces in complex spaces. Samuel Siltanen, Alex Southern, and Lauri Savioja (Department of Media Technology, Aalto University, PO Box 15400, Aalto FI-00076, Finland, Lauri.Savioja@aalto.fi)

Acoustic reflections from rough surfaces occur both in indoor and outdoor environments. Detailed modeling of such reflections is possible with wave-based modeling algorithms. However, their time and resource consumption limits the applicability of such algorithms in practical modeling tasks where the modeled space is large or even unbounded. On the other hand, geometrical acoustics modeling techniques are more efficient in most cases, but they are not able to capture the wave interaction with the rough surface. The presented solution combines a geometric modeling algorithm with a theoretical model of the rough surface. The geometric algorithm is an efficient beam tracer. The theoretical model assumes long wavelength compared to the dimensions of the surface details. The model shows that the effect of the rough surface can be approximated with a exponential decay tail after an impulse in the time domain impulse response. A further approximation is to present multiple such reflections with a decay resembling a gamma distribution. Several complex example cases with a large number of reflections are shown. In addition, comparison of the theoretical model to finite-difference time-domain algorithm modeling results is given. The results support the applicability of the presented approach to practical modeling tasks.

8:25

1aPA2. Computational modeling of broadband acoustic fields in enclosures with specular reflection boundaries using a first-principles energy method. Donald B. Bliss, Krista A. Michalis, and Linda P. Franzoni (Mechanical Engineering, Duke University, Durham, NC 27708, dbb@duke.edu)

Steady-state sound fields in enclosures with specular reflection boundaries are modeled with a first-principle energy-intensity boundary element method using uncorrelated broadband directional sources. The specular reflection field is represented by a limited set of spherical harmonics, orthogonal on the half-space. For each boundary element, the amplitudes of these harmonics are determined from the incident field from all other elements and sources, and are subject to an energy conservation integral constraint using a Lagrange multiplier method. The computational problem is solved using an iterative relaxation method starting from the 3-D diffuse reflection solution. At each iteration, directivity harmonics are estimated by post-processing and the influence matrix is refined accordingly. For internal sources, simple first reflection images improve accuracy with virtually no penalty on computation time. Convergence occurs in relatively few relaxation steps. Extrapolating to an infinite number of boundary elements and iterations gives very accurate results. Results are compared to exact benchmark solutions obtained from a frequency-by-frequency modal analysis, and to a broadband image method. The method of absorption scaling is verified for 3-D cases, and showing that the spatial variation in rooms is largely determined by source position and the relative distribution of absorption, but not the overall absorption level.

8:45

1aPA3. An edge-source integral equation for the calculation of scattering. U. Peter Svensson (Acoustics Research Centre, Department of Electronics and Telecommunications, Norwegian University of Science and Technology, NTNU IET, Trondheim - NO-7491, Norway, svensson@iet.ntnu.no) and Andreas Asheim (Department of Computer Science, Katholieke Universiteit, Heverlee, Belgium)

A new integral equation for the scattering from rigid, or pressure-release, convex polyhedra and disks is presented. It is based on edge diffraction as a complement to the geometrical acoustics components, and uses directional edge sources as unknowns in the frequency-domain integral equation. Comparisons with reference results show that the new method gives correct results down to 0 Hz in spite of being a geometrically based method [Asheim & Svensson, Report TW610, KU Leuven, Dept. of Computer Science, 2012]. The two-dimensional unknowns are solved for all edges, straight or curved, of the scattering object, but this reduces to a one-dimensional unknown for certain geometries such as axisymmetric scattering from a circular thin disk, or plane-wave incidence onto a polygonal cylinder. The general integral equation can be solved with the regular Nyström technique, iteratively or by direct inversion. The scattered field is computed in a post-processing stage, and is added to the geometrical acoustics and first-order diffraction components, which are computed separately. The formulations for non-convex external, as well as internal, geometries are laid out, and time-domain versions of the integral equation are linked to previously published work on edge diffraction impulse responses.

9:05

1aPA4. A fast wave-based hybrid method for interactive acoustic simulation in large and complex environments. Tian Xiao (EE Boost Inc., 618 Powers Ferry RD, Cary, NC 27519, xiao@eeboost.com)

Modern acoustic applications require fast and accurate simulation in large and complex environments. Current methods are rather limited to very simple environments or not able to perform fast interactive simulations. Our objective is to develop an innovative and practical method to perform real-time or near real-time accurate interactive simulation in large and complex environments, such as urban environments up to one kilometer. A new method, the embedded hybrid method using immersed boundary within k-space PSTD has been proposed and developed to achieve the objective. Its performance, accuracy, parallel hardware acceleration, and capabilities to handle all kinds of environmental complexities have been rigorously validated and verified by a number of examples. It shows that with the utilization of modern many-core GPUs, the method can perform real-time or near real-time accurate interactive simulation in large environments of hundreds to thousands of meters with all kinds of complexities including (1) inhomogeneous and absorptive medium, (2) curved and arbitrarily-shaped objects, (3) and moving sources, receivers, and objects, and time-varying medium.

9:25

1aPA5. Adaptive rectangular decomposition: A spectral, domain-decomposition approach for fast wave solution on complex scenes. Nikunj Raghuvanshi (Microsoft Research, 1 Microsoft Way, Redmond, WA 98052, nikunjr@gmail.com), Ravish Mehra, Dinesh Manocha, and Ming C. Lin (Computer Science, University of North Carolina at Chapel Hill, Chapel Hill, Washington)

Computational wave propagation is increasingly becoming a practical tool for acoustic prediction in indoor and outdoor spaces, with applications ranging from noise control to architectural acoustics. We discuss Adaptive Rectangular Decomposition (ARD), that decomposes a complex 3D domain into a set of disjoint rectangular partitions. Assuming spatially-invariant speed of sound, spectral basis functions are derived from the analytic solution and used to time-step the field with high spatio-temporal accuracy within each partition. This allows close-to-Nyquist numerical grids, with as low as 3 points per wavelength, resulting in large performance gains of ten to hundred times compared to the Finite-Difference Time-Domain method. The coarser simulation grid also allows much larger computational domains. ARD employs finite-difference interface operators to transfer waves between adjoining rectangular partitions. We show that efficient, spatially-compact interface operators can be designed to ensure low numerical errors. Numerical solutions obtained with ARD are compared to analytical solutions on simple geometries and good agreement is observed.

9:45

1aPA6. Real-time sound propagation and noise modeling in outdoor environments using Equivalent Source Formulation. Ravish Mehra, Dinesh Manocha, Lakulish Antani (Computer Science, University of North Carolina at Chapel Hill, Columbia Street, Chapel Hill, NC 27599-3175, dmanocha@gmail.com), and Nikunj Raghuvanshi (Microsoft Research, Microsoft, Redmond, WA)

We address the problem of wave-based sound propagation in outdoor and urban environments. The goal is to accurately simulate acoustic effects, including interference, diffraction, scattering, and higher-order wave effects in large outdoor scenes. We give an overview of a precomputed wave-based solver that is based on equivalent source method and is mainly applicable to large, open scenes [Mehra et al. 2012]. As part of a preprocessing step, it computes a per-object transfer function that models the scattering behavior of each object, and handles pair-wise acoustic coupling between objects using inter-object transfer functions. The runtime component involves fast summation over all outgoing equivalent sources for all objects at the listener location. We highlight its runtime performance and memory efficiency and use it for noise modeling and prediction in outdoor scenes spanning a few hundreds of meters. The sound field is computed in three dimensions, modeling frequency-dependent propagation above ceilings, around buildings and corners, and high-order interactions.

10:05–10:25 Break

Contributed Papers

10:25

1aPA7. Coupling of parabolic equation method with the scattering of sound. Santosh Parakkal, D. Keith Wilson, and Sergey N. Vecherin (US Army, ERDC-CRREL-NH, 72 Lyme Road, Hanover, NH 03755, Santosh.Parakkal@usace.army.mil)

The problem of sound scattering by an infinitely long penetrable and impenetrable cylinder suspended over a realistic impedance ground is investigated. The analytical approach using the image source method in the scattering of sound involves expressing the total sound field at any receiver point (over a locally reacting ground) as the sum total of the direct field, the ground reflection from the source, scattered field by the actual cylinder and finally by its image. The exact solutions can then be expressed as an infinite series, containing Bessel and Hankel functions of increasing order. The coefficients of the scattered field are determined by matching the desired boundary condition (for a rigid circular cylinder, for example, the normal component of velocity is zero on the boundary). Although the preceding approach is commonly used in theoretical treatments of sound scattering, to the best of our knowledge this is the first time it has been attempted numerically with coupling to the Parabolic Equation (PE) method. Presented is a Two-dimensional case of sound scattering of PE generated acoustic field by an impenetrable (soft or rigid) and penetrable cylindrical obstacle over a finite impedance ground in a non-refractive atmosphere.

10:40

1aPA8. Time-domain simulation of long-range sound propagation in an atmosphere with temperature gradient. Z. C. Zheng and Guoyi Ke (Aerospace Engineering, University of Kansas, 1530 W 15th Street, Lawrence, KS 66045, zzheng@ku.edu)

A numerical model for linearized Euler equations using finite difference in time-domain (FDTD) simulation is developed to simulate sound propagation with temperature gradient in the atmosphere. The speed of sound in the air varies with the temperature at different altitude above the ground due to the effect of temperature gradient. For sound propagation at long ranges, an algorithm of moving-frame method is implemented with parallel computation. The numerical results are compared with analytical solutions for sound propagation with downward and upward refraction caused by the speed of sound linearly increasing (downward refraction) or decreasing (upward refraction) with altitude. The 2D normal mode analytical solutions are used

to compare the downward refraction results, and the residue series analytical solutions are used to compare the upward refraction results. The comparison show that the numerical simulation results agree very well with the analytical solutions for both downward refraction and upward refraction cases. Several examples of long- and short-range simulation results are then presented.

10:55

1aPA9. Wine glass resonance experiment and demonstration. Benjamin C. Thines (University of Central Arkansas, Conway, AR 72034, thinesbc@gmail.com)

Breaking a wine glass with sound is a visually striking achievement and a great way to get potential students interested in Physics. The goal of this project is to not only break the wine glass but to build an apparatus that is portable and easily setup for lecture room demonstrations as well as outreach to area schools. The apparatus should also provide enough visibility for a room full of observers to easily see the process. In order to be able to observe the small deflections of the object a variable frequency strobe will be employed. A strobe has the benefit of being able to see in real time what is going on at a much higher frequency than the human eye would normally perceive. In a larger setting a camera could be used to relay the relatively small image of the wine glass to a projector for better visibility. From a more technical stand point, the project will provide an opportunity to experiment with resonance on a variety of different shapes and compositions of items. In order to prepare for the final demonstration, many different wine glasses will be tested in the test chamber.

11:10

1aPA10. Aperiodicity and ground effects on the sonic crystal noise barriers. Shahram Taherzadeh, Imran Bashir, Keith Attenborough, and Alvin Y. Chong (MCT, The Open University, Walton Hall, Milton Keynes, Bucks MK7 6AA, United Kingdom, s.taherzadeh@open.ac.uk)

Sonic crystal structures consisting of periodically-arranged solid vertical cylinders can act as sound barriers at certain frequencies. Their performance depends on the filling fraction which is determined by the spacing and cylinder radius. To be effective the filling fraction must be high. This means that periodic arrays with relatively low filling fractions such as in trees belts are not effective as traffic noise barriers. The effects of partially perturbing the positions of sonic crystal elements have been investigated by modelling and laboratory measurements and have been shown to improve the insertion loss of the periodic structure. It is argued that partial perturbation of regular tree planting near highways will improve their noise attenuation. Furthermore, much previous research assumes the sonic crystal structure to be in the free field, i.e. no account has been taken of the presence of the ground surface. With a conventional, wall type, barrier the ground effect is reduced by presence of the barrier. Laboratory measurements have been made of periodic and aperiodic arrays of cylinders placed with their axes normal to acoustically hard and soft surfaces. It is found that the ground effects and sonic crystal band gap effects are additive.

11:25

1aPA11. Partial field decomposition of jet noise using optimally located virtual reference microphones. Alan T. Wall, Kent L. Gee, Tracianne B. Neilsen (Dept. of Physics and Astronomy, Brigham Young University, N283 ESC, Provo, UT 84602, alantwall@gmail.com), and Michael M. James (Blue Ridge Research and Consulting, Asheville, NC)

The application of partial field decomposition (PFD) techniques based on a singular value decomposition to jet noise fields is useful for estimating the number of incoherent (equivalent) noise sources within a jet and for implementing near-field acoustical holography, but it does not generally provide physically meaningful partial fields (i.e. partial fields related to individual sources). Among several PFD methods that were designed to generate physically meaningful partial fields, the method developed by Kim et al. [JASA 115(4), 2004] finds the optimal locations of references in a sound field and places virtual references at those locations. In past investigations this method has been successfully applied to locate discrete numerical and physical sources and to generate partial fields related to each source. In this study, Kim's method is applied to a full-scale jet installed on a military aircraft in an attempt to obtain physically meaningful partial fields. The partial fields obtained using these optimally located virtual references are compared to the partial fields obtained from other PFD methods.

11:40

1aPA12. Observations with grazing and vertical incidence methods of ground impedance estimation. Michael J. White (US Army ERDC/CERL, PO Box 9005, Champaign, IL 61826, michael.j.white@usace.army.mil), George W. Swenson, and Jeffrey D. Borth (Department of Electrical and Computing Engineering, University of Illinois at Urbana-Champaign, Urbana, IL)

At locations near a ground surface of interest, the ground impedance may be evaluated using a loudspeaker suitably disposed to broadcast toward both the ground and two vertically-separated microphones. By evaluating the complex gain ratio between the pair for a single tone, the usual approximation to the Green function for the monopole field above a locally-reacting ground can be inverted to find the surface impedance. This inversion is somewhat sensitive to noise, but it can also be found to vary according to the placement of microphones and speaker, apart from speaker directivity. Recently the method of Soh et al. [Soh et al. JASA 128:5 EL286 2010] was proposed for measuring ground impedance some distance from the source. Because the method relies more directly on the boundary condition at the ground, it may offer some benefit for use at shorter distances as well. We discuss the comparisons between measurements interpreted by both techniques, consider noise entering the estimation process and placement effects.

Session 1aSA

Structural Acoustics and Vibration: Damping Applications and Modeling

Benjamin M. Shafer, Chair
Building Acoustics, Conestoga-Rovers & Associates, Inc., 1117 Tacoma Ave., Tacoma, WA 98402

Invited Papers

9:00

1aSA1. Damping: Some often overlooked facts. Eric E. Ungar (Acentech, Inc., 33 Moulton St., Cambridge, MA 02138-1118, eungar@acentech.com)

Damping - dissipation of mechanical energy - has significant effects on only some types of vibrations. Damping can result from many mechanisms, many of which cannot readily be modeled, but prediction of details of motions requires correct representations of the dominant mechanisms. The assumption of viscous damping permits one to analyze vibrations via relatively easily solved linear differential equations, but can lead to results that do not represent reality. Several measures of damping are based on simple models involving frequency-independent viscous damping, but realistic damping behavior often may be better represented by a frequency-dependent loss factor. The chemical properties of plastics and elastomers generally are not known well enough to permit assessment of the behavior of such materials without dynamic measurements. Structural configurations with relatively high damping may be obtained by combining high-damping polymeric materials with efficient structural materials only if the configurations are such that for a given deformation the high-damping material stores a considerable fraction of the total mechanical energy. This is manifest in the behavior of free-layer and constrained-layer damping treatments and in their design equations, which also indicate that a damping material that is very good for one of these types of treatments may not be good for the other.

9:25

1aSA2. Acoustical performance of damped gypsum board in double wood stud wall assemblies. John LoVerde and David W. Dong (Veneklasen Associates, 1711 16th St, Santa Monica, CA 90404, jloverde@veneklasen.com)

A common assembly for demising walls in multifamily residential projects is double wood studs with multiple layers of gypsum board on one or both sides. While improving the acoustical performance, installing multiple layers of gypsum board adds significant cost to the project; complicates scheduling, materials storage, and delivery; and may require additional inspections. On some types of projects, removing these complications has been desired. In these cases, the use of damped gypsum board has been pursued to reduce the number of layers of gypsum board on the demising wall while attempting to achieve equivalent acoustical performance. Acoustical testing was performed to determine if damped gypsum board was a suitable alternative to the standard gypsum board assemblies in typical demising constructions. Laboratory and field tests were performed on double wood stud walls with a variety of gypsum board configurations, and the results are presented.

9:50

1aSA3. Effects of boundary conditions on the transmission of impulsive sound at low frequencies through building components into enclosed spaces. Marcel C. Remillieux (Mechanical Engineering, Virginia Tech, 149 Durham Hall, Blacksburg, VA 24061, mremilli@vt.edu)

The transmission of impulsive sound at low frequencies, through building components, into enclosed spaces is solved numerically. This investigation is directed at what is essentially a transient problem. The shapes of the vibro-acoustic waveforms, in particular peak values, are of principal concern since they relate directly to the auditory response of occupants and possibility to structural damage. The case of an N-wave impinging upon a window panel backed by a rigid rectangular enclosure is considered in this study. At low frequencies, the vibro-acoustic response of a typical building component is dominated by a few modes. Besides, the response is very sensitive to boundary conditions. Therefore, the vibro-acoustic response of the system can be altered by tuning the boundary conditions of the structural components. Three types of boundary conditions are examined: simply-supported, fixed, and visco-elastic. It is demonstrated that the peak amplitudes of the vibro-acoustic waveforms can be reduced significantly by the appropriate choice of boundary conditions.

10:15–10:30 Break

10:30

1aSA4. Predicting structural and acoustic-radiation loss factors using experimental modal analysis. Micah R. Shepherd, Stephen A. Hambric, and John B. Fahnline (Applied Research Lab, Penn State University, PO Box 30, Mailstop 3220B, State College, PA 16801, mrs30@psu.edu)

Standard damping measurements cannot typically distinguish between structural losses and losses due to acoustic radiation. Since the trend in aerospace engineering is to use lighter and stiffer materials, aerospace panels often have their critical frequency at low to mid frequencies making the acoustic losses of comparable or greater value than the structural loss factors. A procedure for measuring

acoustic radiation loss factors is presented based on experimental modal analysis. Experimental modal analysis was performed on a composite panel with carbon-fiber facesheets and an aluminum honeycomb core. The loss factors using the standard decay and modal methods are compared to an energy-based method based on the power injection method. The acoustic radiation loss factors were then estimated using boundary element computations of the radiated noise with the modally reconstructed velocity as input. The acoustic radiation damping was then removed from the total damping to predict the losses due to structural damping only.

Contributed Papers

10:55

1aSA5. Vibration damping mechanisms for the reduction of sting in baseball bats. Daniel A. Russell (Graduate Program in Acoustics, Pennsylvania State University, 201 Applied Science Bldg, University Park, PA 16802, drussell@engr.psu.edu)

When the impact between a baseball and a bat occurs outside the "sweet-spot" region, the resulting vibration in the handle often produces a stinging sensation in the hands. Pain from a poorly hit ball is primarily felt in the fleshy web between thumb and forefinger in the top (distal) hand, and also to a lesser degree in the heel of the bottom (proximal) hand, and the sensation of sting is more prevalent in aluminum bats than in wood. Several bat manufacturers have attempted to minimize handle vibration in aluminum bats through various methods including handle grips, foam injected into the hollow handle, two-piece construction joining composite handles to aluminum barrels, and the insertion of vibration absorbers in the taper region and in the knob of the handle. This paper will assess and compare the performance of several such vibration damping applications implemented in baseball bats. Experimentally measured damping rates corresponding to the bending mode shapes responsible for sting will be compared for a variety of bat designs. The effectiveness of available commercially implemented damping mechanisms will be compared using frequency response functions and time signals.

11:10

1aSA6. An approach to increase apparent damping with reduced subordinate oscillator array mass. Aldo A. Glean, Joseph F. Vignola, John A. Judge, Teresa J. Ryan (Mechanical Engineering, Center for Acoustics, Vibrations and Structures, Catholic University of America, 620 Michigan Avenue, N.E, Washington, DC 20064, 10glean@cardinalmail.cua.edu), and Patrick F. O'Malley (Mechanical Engineering, Benedictine College, Atchison, KS)

The case of a lightly damped oscillator (primary mass) adorned with a set of substantially less massive oscillators is known as a subordinate oscillator array (SOA). An SOA can function as an energy sink on the primary, extracting vibration energy from it, thus adding apparent damping to the system. Low apparent Q is achieved by increasing non-dimensional bandwidth, which is the ratio of the bandwidth to the fundamental frequency of the primary. The mass of the subordinate set required to achieve the most rapid energy transfer from the primary is proportional to non-dimensional bandwidth squared. We have shown the limit of apparent damping achievable in these systems is the inverse of non-dimensional bandwidth. In practice, the utility of this result is limited because a great deal of mass (~30% of primary) is required to increase the apparent damping in the system such that Q_apparent→1. This work will focus on an alternative design strategy that produces comparable increase in apparent damping with less added mass. We describe numerical optimizations in which the non-dimensional bandwidth of the isolated natural frequencies of the SOA elements and the distribution of those isolated natural frequencies are used to minimize the total mass of the SOA.

11:25

1aSA7. Viscous boundary layer correction on a pressure-field acoustic model. Yizeng Li (Department of Mechanical Engineering, University of Michigan - Ann Arbor, 2350 Hayward Avenue, Ann Arbor, MI 48109, liyizeng52@hotmail.com), Lei Cheng (BOSE Corporation, Framingham, MA), and Karl Grosh (Department of Mechanical Engineering, University of Michigan - Ann Arbor, Ann Arbor, MI)

Fluid viscosity plays an important role in many acoustics and structural acoustics problems. For example, using an inviscid approximation to the flow of fluid-loaded micro-electro-mechanical systems and micro-scale biological structures results in large errors in the predicted response. Using a linearized Navier–Stokes solution, however, increases the number of unknowns by at least a factor of three compared to an inviscid approximation where pressure is the only degree of freedom. In this work, an approximate boundary condition is developed to include fluid viscosity for coupled fluid-structure systems. The viscous effect is included as a correction term to the inviscid boundary condition, written in terms of second order in-plane derivatives of pressure. This is the key step enabling the development of a variational formulation that is directly amenable for approximation in a finite element method (FEM) code as only a minor modification to existing structural acoustic code. Hence, this approach retains the great computational advantage over the conventional viscous FEM formulation. We show results demonstrating the accuracy of the approximate boundary condition as compared to the full three dimensional Navier-Stokes solution.

Session 1pAA

Architectural Acoustics: Performing Arts Center Acoustics–Pre-Tour Talk

Robert C. Coffeen, Cochair
School of Architecture, Design & Planning, Universtiy of Kansas, Lawrence, KS 66045

Norman H. Philipp, Cochair
Geiler and Associates, LLC, 1840 E. 153rd Cir., Olathe, KS 66062

Chair's Introduction—1:35

Invited Papers

1:40

1pAA1. Acoustical design of Calderwood Hall at the Isabella Stewart Gardner Museum. Daniel Beckmann, Motoo Komoda, and Yasuhisa Toyota (Nagata Acoustics, 2130 Sawtelle Bl., Ste. 308, Los Angeles, CA 90025, beckmann@nagata.co.jp)

The Isabella Stewart Gardner Museum opened the expansion to its historic "Fenway Court" Palace in the Back Bay district of Boston, Massachusetts in January, 2012. Renzo Piano Building Workshop was the design architect for the 70,000 square foot addition to the museum. The new Calderwood Hall serves the music programming mission of the museum by creating a 300-seat space where chamber music can equally be enjoyed by all members of the audience. A novel audience configuration is perhaps the most defining element of this highly intimate space for music, where a stage measuring 30 feet square is centered on the bottom level of the space measuring 42 feet square and 45 feet tall. Three stacked balconies, each one row deep, look down on the stage from all four sides. The integrated acoustical and architectural design features are reported.

2:00

1pAA2. Acoustical design of Muriel Kauffman Theatre at the Kauffman Center for the Performing Arts. Motoo Komoda, Kayo Kallas, Daniel Beckmann, and Yasuhisa Toyota (Nagata Acoustics, 2130 Sawtelle Bl., Ste. 308, Los Angeles, CA 90025, komoda@nagata.co.jp)

Muriel Kauffman Theatre, the horseshoe-style proscenium theater in the Kauffman Center for the Performing Arts in Kansas City, Missouri, opened in September, 2011. The 1800-seat theater was designed by the architect Moshe Safdie, and serves as the principal residence of both the Kansas City Ballet, and the Lyric Opera of Kansas City. Since ballet and opera performance were programmed as the primary use, the primary focus of the room acoustical design was to provide good natural acoustics for singers on the stage, and for the orchestra in the pit. This was achieved through careful study on the shape of the room. The walls surrounding the stage and proscenium, and the configuration of the ceiling were among the primary aspects of the room shape which were studied, as well as flexible room acoustics for programs with using amplified sound, such as pop music and spoken-word programs. The acoustical design and characteristics of the Muriel Kauffman Theatre are reported.

2:20

1pAA3. Acoustical design of Helzberg Hall at the Kauffman Center for the Performing Arts. Daniel Beckmann, Kayo Kallas, Motoo Komoda, and Yasuhisa Toyota (Nagata Acoustics, 2130 Sawtelle Bl., Ste. 308, Los Angeles, CA 90025, beckmann@nagata.co.jp)

Helzberg Hall, the arena-style concert hall in the Kauffman Center for the Performing Arts in Kansas City, Missouri opened in September, 2011. The 1600-seat concert hall was designed by the architect Moshe Safdie, and serves as the principal residence of the Kansas City Symphony. The hall measures 150 feet long, 100 feet wide, and 90 feet tall at the highest point, with an ensemble reflector suspended at 50 feet above the stage to support the stage acoustics. Stage acoustics are also enhanced by motorized risers on the stage, to give the orchestra layout a three-dimensional quality. Motorized draperies concealed in the walls also give flexibility to the acoustics of the space, in order to accommodate amplified events. A 1:10 scale model test of the hall was performed at the end of the design phase to verify the acoustics of the hall. The acoustical design and characteristics of the new space are reported.

Session 1pAB

Animal Bioacoustics, Engineering Acoustics, and Signal Processing in Acoustics: Echolocation, Bio-Sonar, and Propagation

Whitlow W. L. Au, Chair
Hawaii Institute of Marine Biology, University of Hawaii, Kaneohe, HI 96744

Contributed Papers

1:30

1pAB1. Bio-sonar signal processing. Harry A. DeFerrari and Jennifer Wylie (Applied Marine Physics, University of Miami, 4600 Rickenbacker Cswy, Miami, FL 33149, hdeferrari@rsmas.miami.edu)

An ideal sonar for biological observations in the ocean should employ very long signals for Doppler resolution, wide bandwidth for time resolution and pulse compression properties for gain in order to reduce sound pressure levels to mitigate marine mammal concerns. Signal spread in time and Doppler (leakage) must also be eliminated so that direct arrival and reverberation signals do not leak and swamp bio-signal returns when operation in a continuous transmit and receive mode. Orthogonal codes would help multi-static applications. Here two types of signals and processing are presented and analyzed; 1) M-sequences with matched filter processing and 2) Inverted binary sequence with matched- inverse processing. Ambiguity diagrams of conventional active sonar signals are compared with the two candidate signals. Then the two methods are compared by numerical simulation for propagation in shallow channels with zero Doppler returns and moving bio-scatterers. It is shown that for realistic conditions leakage from direct and zero Doppler reverberation can be eliminated not just reduced. Limits on temporal coherence times of shallow water propagations channels are discussed. These approaches improve Figure of Merit of conventional active sonar by 10 to 15 dB and displays in the time Doppler plane simplify the interpretation of clutter.

1:45

1pAB2. Effects of local shape features on the beampatterns of a dynamic biomimetic baffle. Mittu Pannala, Sajjad Z. Meymand, and Rolf Mueller (Mechanical Engineering, Virginia Tech, 1110 Washington Street, SW, Blacksburg, VA 24061, mpannala@vt.edu)

Horseshoe bats have mobile pinnae that can change their shapes as a result of active actuation. A common pattern is an alteration between an upright and a bent-tip geometrical configuration. Numerical predictions of reception beampatterns associated with these different shape geometries have indicated that the upright configurations are associated with beampatterns dominated by a single mainlobe whereas the bent-tip configurations have prominent sidelobes. Using a biomimetic baffle prototype, we have found that this effect can be reproduced qualitatively with just a plain obliquely truncated cone that is fabricated from flexible material (rubber) and bent at the tip. However, local shape features can have a strong impact on the quantitative expression of this effect. The three features studied here were a vertical ridge, an equivalent to the bat's antitragus, and a lateral incision into the baffle rim. The effects of these features on the beampatterns where found to interact with each other and also depend strongly on the deformation stage of the baffle shape. Hence the corresponding biological features may offer bats an opportunity to fine-tune their beampatterns as a function of deformation stage. However, control strategies for biomimetic devices with variable beampatterns have yet to be developed.

2:00

1pAB3. Analysis of biosonar beamwidth with spherical harmonics power spectra. Mohammad Motamedi (Mechanical Engineering, Virginia Tech, Blacksburg, VA 24060, m.motamedi.85@gmail.com), Qiuping Xu, Washington Mio (Mathematics, Florida State University, Tallahassee, FL), and Rolf Mueller (Mechanical Engineering, Virginia Tech, Blacksburg, VA)

Ultrasound emission and reception in bats are characterized by beampatterns that can be predicted from digital models of the geometries of noseleaf and pinna structures numerically. One obvious way in which beampatterns can differ across species is in the overall width (angular extent) of the beams. But since biosonar beams also vary in many other ways such as in their orientation and their shape, quantifying overall beamwidth poses a challenge. Here, the power spectrum of a beam decomposition based on spherical harmonics has been used to obtain a quantitative measure of beamwidth. Due to the reciprocity between transform domains, narrower beams correspond to spectra with a higher bandwidth and vice versa. Using power spectral magnitudes, it has been possible to classify emission and reception beampatterns as well as beampatterns from different taxonomic bat groups across 176 noseleaf and 185 pinna samples representing 106 species. Furthermore, when the power spectra of the actual biosonar beams were replaced with those of fitted single heat functions, classification performance suffered little. Since the heat kernel approximations did not differ in any property other than beamwidth, this demonstrates that beamwidth alone is a discriminating factor between bat taxonomic groups as well as emission and reception.

2:15

1pAB4. Examining the effects of propagation on perceptual features used for automatic aural classification. Carolyn M. Binder, Paul C. Hines, Sean P. Pecknold, and Jeff Scrutton (Defence R&D Canada, P.O. Box 1012, Dartmouth, NS B2Y 3Z7, Canada, carolyn.binder@drdc-rddc.gc.ca)

A prototype aural classifier has been developed at Defence R&D Canada that uses perceptual signal features which model the features employed by the human auditory system. Previous effort has shown the classifier reduced false alarm rates and successfully discriminated cetacean vocalizations from several species. The current paper investigates the robustness of the aural features against propagation effects for two of those species - the bowhead and humpback whales. This is achieved by comparing the classification results of the original vocalizations to classification results obtained after the vocalizations were re-transmitted underwater over ranges of 2 to 10 km. To gain additional insight into the propagation effects, synthetic bowhead and humpback vocalizations, with features similar to the most important aural features for classification of bowhead and humpback vocalizations, were also transmitted. In this paper, the classifier performance on both real and synthesized vocalizations are compared before and after propagation, to quantify the effect of propagation on the features used in the aural classifier.

2:30

1pAB5. Propagation modeling techniques for marine mammal management studies. Elizabeth T. Küsel, Martin Siderius, and Scott Schecklman (Northwest Electromagnetics and Acoustics Research Laboratory, Portland State University, 1900 SW 4th Ave., Portland, OR 97201, kusele@alum.rpi.edu)

Acoustic propagation modeling techniques are often used to estimate the impact of anthropogenic sound sources on the marine environment, and to estimate population density and detection ranges of marine mammals from their vocalizations. Sophisticated propagation models can be used to accurately calculate acoustic transmission loss as a function of range and depth. This is often done along a number of uniformly spaced radials surrounding a sound source and results are interpolated to each simulated animal location. Computational time, detailed input parameters, and interpolation over complex bathymetry can be a hindrance to efficient and accurate results. This work investigates the impact of using simple propagation modeling that avoids interpolation between radials. Differences will be compared between direct and interpolated values as well as between coherent and incoherent transmission loss solutions. The accuracy and efficiency of the different approaches are evaluated by comparing the number of animals that would be taken by the sound field, which are associated with randomized animal locations in Monte Carlo simulations. [Work supported by ONR.]

2:45

1pAB6. Passive acoustic detection and classification of *Ziphius cavirostris*. Ryan Goldhahn (NATO Undersea Research Centre, Viale San Bartolomeo, 400, La Spezia 19126, Italy, goldhahn@nurc.nato.int)

Cuvier's beaked whales, Ziphius cavirostris (Zc), are a species of marine mammals particularly sensitive to anthropogenic noise. Estimating their habitats and abundance is thus of particular importance when planning and conducting active sonar exercises. Since their deep-diving behavior make them difficult to observe visually, passive acoustics is frequently used for detection. A method of automatic detection and classification of Zc is presented based on the inter-click interval, click spectrum, and direction of arrival estimated on a volumetric array. Specifically, click spectra are compared against a signal subspace constructed from eigenvectors of previously identified beaked whale clicks. The direction of arrival is estimated by cross correlating the received click across a three-dimensional array and clicks are classified based on their estimated elevation angle. Additionally, since Zc are known to produce click trains rather than single clicks, detections made without neighbouring detections are discarded as interference. These three criteria are used to detect and classify Zc, in the presence of dolphin clicks and/or other interference. Results are presented on data collected during the SIRENA10 and SIRENA11 experiments conducted by the NATO Undersea Research Centre in the Atlantic Ocean and Mediterranean Sea respectively, and compared against detections made by human operators and a team of visual observers.

3:00

1pAB7. Interesting properties of toothed whale buzz clicks. Odile Gerard (LSM, DGA TN, Avenue de la Tour Royale, Toulon 83000, France, odigea@gmail.com), Craig Carthel, and Stefano Coraluppi (Fusion Technology and Systems, Compunetix, Inc., Monroeville, PA)

Toothed whales are known to click to find prey. The characteristics and repetition rates of the echolocation clicks vary from one species to another, but clicks are fairly regular during the phase in which the animals are searching for prey. Once they have found prey the repetition rate of the clicks increases; these sequences are called buzzes. Some previous work was done to classify Blainville's beaked whale buzz clicks. While we did not succeed to classify these clicks individually because of the variation of their characteristics, we found buzz clicks have slowly varying properties from one click to the next. This similarity permits their association as a sequence using multi-hypothesis tracking algorithms. Thus buzz classification follows the automatic tracking of clicks. We also found that buzz clicks from other toothed whales species often have similar properties. In some cases a variant of this property has been found, whereby sub-sequences of clicks also exhibit slowly varying characteristics.

Session 1pAO

Acoustical Oceanography and Underwater Acoustics: Memorial Session in Honor of Clarence S. Clay II

Dezhang Chu, Cochair
NOAA Fisheries, NWFSC, Seattle, WA 98112

John K. Horne, Cochair
School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA 98195

J. Michael Jech, Cochair
Northeast Fisheries Science Center, Woods Hole, MA 02543

Timothy K. Stanton, Cochair
Woods Hole Oceanographic Institution, Woods Hole, MA 02543-1053

Contributed Papers

1:00

1pAO1. Feature extraction for classification of fish species using the Cepstral analysis. Ikuo Matsuo, Masanori Ito (Department of Information Science, Tohoku Gakuin University, Tenjinzawa 2-1-1, Izumi-ku, Sendai, Miyagi 9813193, Japan, matsuo@cs.tohoku-gakuin.ac.jp), Tomohito Imaizumi, Tomonari Akamatsu (National Research Institute of Fisheries Engineering, Fisheries Research Agency, Hasaki, Ibaraki, Japan), Yong Wang, and Yasushi Nishimori (Furuno Electric Co., Ltd, Nishinomiya, Hyogo, Japan)

Identification and classification of fish species are essential for acoustic surveys of fisheries. The echo from the fish contains components from multiple reflections, including the swimbladder and other organs. The target strength (TS) and temporal structure, which were measured and analyzed by using the broadband signal, were changed dependent on the incident angles and fish species. The cepstral analysis, which was defined as the inverse Fourier transform, was used to discriminate between the spectral pattern associated with the swim bladder and the interference pattern associated with these reflections. Echoes of Japanese jack mackerel (Trachurus japonicus), chub mackerel (Scomber japonicus), and red sea bream (Pagrus major) were measured and analyzed in the sea and tank. It was clarified that the spectral pattern associated the swim bladder was strongly dependent on both the tilt angle and the fish species. [Supported by the Research and Development Program for New Bio-industry Initiatives, and CREST, JST.]

1:15

1pAO2. Exploring the capabilities of an 18-kHz split-beam scientific echosounder for water column mapping and seafloor positioning of methane seeps in the northern Gulf of Mexico. Kevin Jerram, Thomas C. Weber, and Jonathan Beaudoin (Center for Coastal and Ocean Mapping, University of New Hampshire, 24 Colovos Road, Durham, NH 03824, kjerram@ccom.unh.edu)

Underwater methane seeps support diverse biological communities on the seafloor and, in cases of bubble survival to the surface, contribute to the quantity of atmospheric methane. The National Oceanic and Atmospheric Administration (NOAA) ship *Okeanos Explorer* completed two research cruises for seep mapping and characterization in the northern Gulf of Mexico during August and September of 2011 and April of 2012. A 30-kHz Kongsberg EM 302 multibeam echosounder (MBES) and an 18-kHz Simrad EK60 split-beam scientific echosounder were employed to detect and observe seeps during multiple transects over areas of known seep activity at depths of approximately 1500 m. This presentation includes analyses of EK60 data from both research cruises with emphasis on seep mapping in the water column and seep source positioning on the seafloor using EM 302 MBES observations of seeps as benchmarks. Uncertainty associated with interferometric principles employed by the EK60 and limits to midwater positioning capability imposed by its beam pattern are discussed. The importance of sound speed measurement at the transducer face and the effects of refraction correction are estimated by comparison of isovelocity and constant-velocity layer models using sound speed profiles collected during the research cruises.

1:30

1pAO3. Observation of sound fluctuations in presence of internal waves: Difference between refractive and adiabatic regimes. Mohsen Badiey (College of Earth, Ocean, and Environment, University of Delaware, 261 S. College Ave., Robinson Hall, Newark, DE 19716, badiey@udel.edu) and Boris G. Katsnelson (Department of Physics, Voronezh State University, Voronezh, Russian Federation)

Angular dependence of sound field on the internal solitary wave propagation in shallow water has been previously shown [JASA, vol.122, p747-760, 2007]. In the presence of moving nonlinear internal waves, the interaction between sound field and internal waves can vary from refractive, to adiabatic, and mode coupling regimes. The mechanism is largely dependent on the angle between the direction of an acoustic track and wave front of internal waves. For small angles, refraction of horizontal field (focusing and de-focusing) can occur. However, for larger angles, the characteristics of the interaction between the acoustic field and internal waves is very different. For example for angle of about 15-20 degrees, the variations of the sound field follow variations of the sound speed profile while for the angle of about 5 degrees, focusing is observed. In this paper experimental observations and the corresponding modeling results showing the difference between the sound field for the small and larger angles are presented. This observation has prompted theoretical investigation [shown in an accompanying paper, Katsnelson, Badiey, et al.] showing the analytical aspect of the problem. Good agreement between the model and the experimental data is shown. [Work was supported by ONR.]

1:45

1pAO4. Mode-2 internal wave generation and propagation-impact on acoustic signal properties. Marshall H. Orr (Acoustics Division, The Naval Research Laboratory, 4555 Overlook Ave SW, Washington, DC 20375, rubyspiral@gmail.com) and Thomas E. Evans (Remote Sensing Division, The Naval Research Laboratory, Washington, DC)

Mode 2 internal wave spatial distributions, generation, propagation and dissipation in the vicinity of bathymetry variably on the continental shelf and near the shelf break of New Jersey, USA will be overviewed for early fall oceanographic conditions. The 3-D spatial and temporal evolution of the mode 2 waves, as simulated with the Naval Research Laboratory nonhydrostatic Model for Coastal Oceans, will be compared to tow-yo conductivity, temperature and depth (CTD) and high frequency acoustic flow visualization observations of mode -2 internal waves. Sound speed field perturbation and acoustic field spatial and temporal distributions in the presence of mode-2 internal waves will be summarized.

2:00

1pAO5. Ecosystem-based management: What would Clay do? J. Michael Jech (NEFSC, 166 Water St., Woods Hole, MA 02543, michael.jech@noaa.gov)

Fisheries resource management is in a state of transition from managing populations at the species level to managing living marine resources at the ecosystem level. This transition will require changes in the way data are collected, analyzed, integrated, and finally utilized in management decisions. C. S. Clay "Clay" was a pioneer in underwater acoustics, but my first experiences and interactions with him were as a graduate student biologist learning to observe and understand the underwater environment in new and innovative ways. Clay's collaborations with biologists, ecologists, and oceanographers spawned novel methods of integrating and analyzing disparate data sets and many of these methods are being used today. While Clay's influence on fisheries acoustics has been monumental, his approaches to understanding the ocean environment may be most valuable to ecosystem-based management strategies. I will highlight examples of Clay's innovative approaches that have been used and ways they could be applied to ecosystem-based management and research.

MONDAY AFTERNOON, 22 OCTOBER 2012 BENNIE MOTEN A/B, 2:00 P.M. TO 4:30 P.M.

Session 1pID

Interdisciplinary: Introduction to Technical Committee Research and Activities: Especially for Students and First-Time Meeting Attendees

Eric A. Dieckman, Cochair
Dept of Applied Science, College of William and Mary, Williamsburg, VA 23187

Samuel L. Denes, Cochair
Acoustics, Pennsylvania State Univ., University Park, PA 16802

Chair's Introduction—2:00

Invited Papers

2:05

1pID1. Introduction to animal bioacoustics. Holger Klinck (Cooperative Institute for Marine Resources Studies, Oregon State University and NOAA Pacific Marine Environmental Laboratory, Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, OR 97365, Holger.Klinck@oregonstate.edu)

Animal bioacoustics (AB) covers all matters related to the production, transmission, and reception of sound in nature, as well as the investigation and use of natural sound by people and impacts of anthropogenic sounds by on animals. Topics include animal communication; sound production mechanisms; sound reception mechanisms; evolution of sound production and hearing mechanisms; effects of acoustic propagation on natural sounds; sound detection, classification, localization and tracking; estimating populations and population density; impact of human-generated noise on animals; and a variety of other topics. All animals, and indeed all organisms, are considered within the scope of AB, though the most common taxa are marine mammals, birds, primates and other mammals, fishes, frogs and other amphibians, and insects.

2:15

1pID2. An introduction to the Biomedical Acoustics Technical Committee. Robert McGough (Department of Electrical and Computer Engineering, Michigan State University, 2120 Engineering Building, East Lansing, MI 48824, mcgough@egr.msu.edu)

An overview of the activities of the Biomedical Acoustics Technical Committee will be presented, along with a brief survey of some of the ongoing research projects in Biomedical Acoustics. For example, the Biomedical Acoustics Technical Committee organizes a student poster competition every year, and special sessions are arranged at each meeting to highlight some of the latest research in the diagnostic and therapeutic applications of acoustics. Some of the topics include ultrasound imaging, high intensity focused ultrasound, ultrasound mediated drug delivery, ultrasound contrast agents, ultrasound-induced cavitation, and ultrasound elastography, among several others. In this presentation, selected examples of active research topics in Biomedical Acoustics will also be described in greater detail.

2:25

1pID3. Psychological and physiological acoustics: From sound to neurons to perception … to clinical and engineering applications. Michael Heinz (Speech, Language, and Hearing Sciences & Biomedical Engineering, Purdue University, 500 Oval Drive, West Lafayette, IN 47907, mheinz@purdue.edu)

Psychological and physiological acoustics includes a wide range of multidisciplinary approaches and topics, ranging from basic science to clinical and engineering applications. Research in this area of acoustics is concerned with questions such as how sound is processed once it enters the auditory system (both in humans and other species), how sound is used by organisms to help them communicate and navigate their environment, and how experience and pathology can alter the signal processing of sounds through neural plasticity. Topics include the biomechanics of the middle and inner ear; the neuroscience of the auditory nerve, brainstem, and cortex (including both upward and downward connections); and behavioral and cognitive studies of auditory perception. This talk provides a brief overview of several current areas of research, ranging from basic questions about the neural codes that represent various features of sound in the peripheral and central auditory systems, to clinical applications including the development and improvement of cochlear, brainstem, and midbrain implants that bypass the peripheral auditory system to restore hearing to people with profound hearing loss.

2:35

1pID4. An introduction to current research in Speech Communication. Tessa Bent (Department of Speech and Hearing Sciences, Indiana University, 200 S. Jordan Ave., Bloomington, IN 47405, tbent@indiana.edu)

Speech is a highly complex acoustic signal yet most people can produce and understand speech rapidly and without error. Researchers in Speech Communication—including speech and hearing scientists, linguists, psychologists, and engineers—are deepening our understanding of this amazing process. Topics covered by the Speech Communication Technical Committee include speech production, perception, and acquisition; acoustic phonetics; speech and hearing disorders; neuroscience of speech production and perception; speech intelligibility; communicative aspects of singing; speaker classification and identity; audiovisual speech perception; and speech processing and technology. This presentation will provide a brief overview of some current research areas within Speech Communication including speech acquisition in first language, second language, and bilingual contexts; the impact of speech and hearing disorders on communication; imaging and modeling of speech production using new technologies; and adaptation to novel speech stimuli throughout the lifespan.

2:45

1pID5. Architectural acoustics—Space for sound, and you. Alex Case (Sound Recording Technology, University of Massachusetts Lowell, 35 Wilder St, Suite 3, Lowell, MA 01854, alex@fermata.biz)

The discipline of Architectural Acoustics consistently produces more than 100 papers across 6 or more special sessions, at each meeting of the ASA. Student paper awards, student design competitions, and Knudsen lectures augment these activities. Joint sessions, particularly with Noise, Musical Acoustics, Psychological and Physiological Acoustics, and Signal Processing in Acoustics, add more still to the architectural acoustics goings-on at every ASA conference. The sphere of influence is not limited to ASA alone, as TCAA members participate in the Green Construction Code of the International Code Council, Society of Motion Picture and Television Engineers Study Group: Movie Theater Sound System Measurement and Adjustment Techniques, Classroom Acoustics Standards, the American Institute of Architects Continuing Education System, and more. This busy committee also produces a steady stream of publications documenting recent work and deciphering standards for key stakeholders. Anyone with an interest in the field will find many opportunities to advance their own expertise, build a network of colleagues, friends and mentors, and contribute to the essential activities of the Technical Committee on Architectural Acoustics.

2:55

1pID6. Introduction to the Structural Acoustics and Vibration Technical Committee. James E. Phillips (Wilson, Ihrig & Associates, Inc., 6001 Shellmound St., Suite 400, Emeryville, CA 94608, jphillips@wiai.com)

The Structural Acoustics & Vibration Technical Committee (SAVTC) includes the study of motions and interactions of mechanical systems with their environments and the methods of their measurement, analysis, and control. This talk will provide a broad overview of the many research areas of interest to SAVTC. A few topics will be explored in more depth to provide background on some of the more common analysis methods used by members of the technical committee.

3:05–3:20 Break

3:20

1pID7. Noise and its impact on our world. Erica Ryherd (Mechanical Engineering, Georgia Institute of Technology, Mechanical Engineering, Atlanta, GA 30332-0405, erica.ryherd@me.gatech.edu)

Noise invades all aspects of our lives. The word noise is actually derived from the Latin word “nausea”, with one possible connection being that unpleasant sounds were made by seasick passengers or sailors in ancient times. In modern times, the demand for noise research and consulting has intensified in concert with rising population densities, growing industrialized societies, escalating demands from consumers, and increasingly common standards and legislation related to noise. The Acoustical Society of America Technical Committee on Noise (TC Noise) is concerned with all aspects of noise, ranging from noise generation and propagation, to active and passive methods of controlling noise, to the effects of noise on humans and animals. This talk will explore the broad topic of noise and its impact on our world.

3:30

1pID8. The Engineering Acoustics Technical Committee. Michael V. Scanlon (US Army Research Laboratory, 2800 Powder Mill Road, Adelphi, MD 20783-1197, michael.v.scanlon2.civ@mail.mil)

Engineering Acoustics Technical Committee (EATC) encompasses the theory and practice of creating tools for investigating acoustical phenomena and applying knowledge of acoustics to practical utility. This includes the design and modeling of acoustical and vibrational transducers, arrays, and transduction systems in all media and frequency ranges; instrumentation, metrology, and calibration; measurement and computational techniques as they relate to acoustical phenomena and their utility; and the engineering of materials and devices. EATC's recently sponsored special sessions attracted members from all areas and is an enabler for overlapping interests: single crystal piezoelectrics, transducer design, vector sensors, materials for high power sonar, micromachined silicon mics, multimedia, 3-D audio, pro-audio, parametric sources, speakers, transduction, projection, materials processing and manufacturing, piezocomposites, sensor fusion, signal processing hardware, data communication, condition-based monitoring of machinery and processes, solid-state sensors and actuators, hearing aids and ear impedance, thermoacoustic refrigerators and engines, wind turbines, energy harvesting, computer modeling methods, acoustic barriers & noise control, array applications, metamaterials, systems for underwater vehicles, mufflers & silencers, borehole acoustics, flow noise mitigation methods, and non-destructive testing with ultrasound & non-contact methods.

3:40

1pID9. Signal processing in acoustics: Why not get involved? R. L. Culver (ARL, Penn State University, PO Box 30, State College, PA 16804, rlc5@psu.edu)

The Signal Processing Technical Committee (SPTC) of the ASA provides a forum for discussion of signal processing techniques that transcend any one application. Signal processing research typically presented at ASA meetings includes techniques that show promise in one application - say underwater acoustics - but may also have application to other areas, for example, speech processing or room acoustics. There are two good reasons to get involved in the SP TC. First, since signal processing is an important aspect of many acoustic research areas, you will have the opportunity to better understand new and potentially useful tools. Second, we are a small TC and you can make an immediate contribution.

3:50

1pID10. An introduction to the Physical Acoustics Technical Committee activities. Steven L. Garrett (Grad. Prog. in Acoustics, Applied Research Lab, Penn State University, P.O. Box 30, State College, PA 16804, sxg185@psu.edu)

The primary activity of any ASA Technical Committee is to use collective wisdom of the Committee's membership to determine which research topics within its specialization area are most active and interesting. Based on that assessment, the Committee organizes special sessions at future meetings that will bring together experts from those areas, not necessarily limited to the Society members, who can share interesting results and provide guidance regarding the directions that will lead to further understanding. In Physical Acoustics, that is a particularly daunting challenge given the scope of topics that fall within its purview: use of sound to probe material properties, sound propagation and attenuation mechanisms on this planet and in other parts of the universe, and physical effects of sound and its interaction with other forms of radiation, all of which could also go well beyond the limitations of a linear acoustical theory. Needless to say, involvement in debates about "what's hot" is both interesting and educational. Other activities include proposals for Technical Initiatives that allocate ASA resources. Recently, PATC received funding to sponsor a demonstration session at the Physical Acoustics Summer School.

4:00

1pID11. Overview of Acoustical Oceanography Technical Committee. Aaron Thode (SIO, UCSD, 9500 Gilman Dr, MC 0238, La Jolla, CA 92093-0238, athode@ucsd.edu)

The Acoustical Oceanography (AO) technical committee focuses on the use of sound to study physical and biological processes in the ocean. The broad scope of the committee ensures that many of the research topics overlap those in Underwater Acoustics and Animal Bioacoustics. This presentation will review representative aspects of AO, including long range acoustic tomography, air-sea interactions via studying bubble plumes, fisheries acoustics, and marine mammal acoustic tracking.

4:10

1pID12. An introduction to the Underwater Acoustics Technical Committee. Marcia J. Isakson (Applied Research Laboratories, The University of Texas at Austin, 10000 Burnet Road, Austin, TX 78713, misakson@arlut.utexas.edu)

Acoustics is considered the best means of remote sensing in oceans, lakes, and estuaries due to the high attenuation of electromagnetic radiation in water. The members of the underwater acoustics technical committee are concerned with the generation and propagation of sound in an underwater environment as well as acoustic reflection and scattering from the seabed, sea surface and objects in the water column and on or beneath the seabed. In this talk, a short history of underwater acoustics will be followed by an overview of the current state of research in the field.

4:20

1pID13. An overview of the Musical Acoustics Technical Committee. Andrew Morrison (Joliet Junior College, 1215 Houbolt Rd, Natural Science Department, Joliet, IL 60431, amorrison@jjc.edu)

The technical committee on musical acoustics (TCMU) is concerned with the application of science and technology to the field of music. Many of the sessions organized by the TCMU focus on a particular family of musical instruments. At many Acoustical Society meetings the TCMU has arranged for musical performances related to one or more special sessions. The TCMU has also arranged for tours of sites in the community around past meeting locations. An overview of what students and relative newcomers to the society can expect from the TCMU in general will be presented as well as highlights of what to see at this meeting.

Session 1pMU

Musical Acoustics: Acoustics of the Pipe Organ

Uwe J. Hansen, Chair
Indiana State University, Terre Haute, IN 47803-2374

Invited Papers

1:00

1pMU1. The Research Organ at the Fraunhofer IBP in Stuttgart. Judit Angster (Acoustics, Fraunhofer IBP, Nobelstr 12, Stuttgart 70569, Germany, angster@ibp.fhg.de) and András Miklós (Applied Acoustics, Steinbeis Transfer Center, Stuttgart, Baden Wuerttemberg, Germany)

At the Fraunhofer IBP in Stuttgart a research organ has been built for scientists. Its transparency and unique design allows the demonstration of research results, the investigation of technical and sound problems in organ building as well as the audible testing of sound ideas. Some of the special design features are: The wind system can be switched from traditional to innovative design. Newly developed swell shutters which allow a better dynamic of the sound are mounted in the swell organ. The dimensioning of pipes and wind systems was conducted by means of scaling software developed within the context of European research projects. One wind chest of a division can be exchanged to allow the testing of valves and pipe layouts. In order to test newly designed stops a blind slider is available. There are several blind grooves to analyze the effect of wind flow, of resonances in the grooves and of different outlet holes on the pipe sound. The blowers are driven by a frequency converter for continuous adjustment of wind pressures. The motion of a beating and a free reed can be visualized by means of a stroboscope installed. Some of the research results will be demonstrated.

1:20

1pMU2. The challenge of orchestrating for the organ and the orchestra. Jason L. Raymond (Biomedical Engineering Program, College of Engineering and Applied Science, University of Cincinnati, CVC 3940, 231 Albert Sabin Way, Cincinnati, OH 45267-0586, raymonjl@mail.uc.edu), Christina Haan (College-Conservatory of Music, University of Cincinnati, Cincinnati, OH), and Christy K. Holland (Department of Internal Medicine, Division of Cardiovascular Diseases, College of Medicine, University of Cincinnati, Cincinnati, OH)

Hector Berlioz (1803-1869), though not an organist himself, included descriptions of organ stops, registration, pitch range, and use in orchestral compositions in his Grand Traité d'Instrumentation et d'Orchestration modernes (1855). When discussing the unsuitability of combining the organ with the orchestra, he stated, "…the even and uniform tones of the organ can never fuse completely with the extremely variable sounds of the orchestra…." The objective of our study was to use this statement as a hypothesis to be tested. The relative dissonance of selected organ stops in combination with four orchestral instruments was analyzed using quantitative frequency analysis techniques. Three organs were chosen for study, each built by a different organ company, and each in a different acoustic setting. Four orchestral instruments (violin, flute, oboe, and horn) were chosen for their contrast in timbre and method of sound production. The differences in pitch between the overtones of the organ and instrument were compared in order to quantify the relative dissonance produced by each combination as a function of critical bandwidth of the human ear. In general, the combinations with the oboe and flute resulted in frequency differences less than 2% of the critical band for each overtone, which were perceived as minimally dissonant. In some cases, the violin and horn overtones exceeded 2% and 4% of the critical band, respectively.

1:40

1pMU3. Scanning vibrometry studies of reed dynamics in reed organ pipes. Thomas M. Huber, Lucas Seewald (Physics, Gustavus Adolphus College, 800 W College Ave, Saint Peter, MN 56082, huber@gac.edu), and Charles Hendrickson (Hendrickson Organ Company, Saint Peter, MN)

Unlike most other wind instruments, in reed organ pipes it is not the length of the resonator tube that primarily determines the pitch, but the length of the vibrating reed. The reed, its fluid-structure interaction with the airflow, and feedback from the resonator form a very complicated dynamical system. By utilizing a Polytec PSV-400 scanning laser Doppler vibrometer, it is possible to monitor the operating deflection shapes of a vibrating reed, while using a microphone to monitor the sound production. In the current study, an experienced organ builder made adjustments to the reed/resonator/airflow parameters, both within a musically appropriate range, and for ranges outside of the norm. Results will be presented of the acoustical and vibrational spectral envelope, and the corresponding deflection shapes for each harmonic, for a range of different adjustments to the system. The vibrational results for the reed will be compared to measurements where the non-contact ultrasound radiation force is used to excite the natural resonance frequencies and deflection shapes of the reed in the absence of airflow. In addition to steady-state deflection shapes, results will be presented for the transient dynamics of the system as the airflow into the pipe is initiated.

2:00

1pMU4. Categorical sound characteristics of free-reed pipe-organ stops. Jonas Braasch (School of Architecture, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY 12180, braasj@rpi.edu)

Organ pipes with free reeds became very popular in parts of Europe at the end of the 18th century, but vanished about 100 years later following a critical discussion about their characteristic sound qualities. The research reported here is based on the measurement and analysis of 11 free-reed organ stops and 15 striking-reed organ stops, as well as 7 flue-pipe organ stops for comparison purposes. The results show that the sound characteristics between free-reed and striking-reed pipes are perceptually distinguishable. Both types of reed stops have their unique set of characteristics. In general, striking-reed pipes have a higher spectral centroid than free-reed pipes. While the overtone spectra of the latter can be fairly similar to those of flue pipes, their onset characteristics do not match the other two types of pipe organ stops. Their fundamental frequencies gradually increase by a semitone over the duration of approximately 60 ms. The frequency shift can be larger for striking-reed pipes, but the duration of the shift is less than half the value for free reeds. In contrast, flue pipes do not usually show such a characteristic frequency shift.

2:20

1pMU5. Aeolian-Skinner Opus 1309 in the Community of Christ Auditorium, Independence, Missouri, USA. Michael Quimby (Quimby Pipe Organs, Inc., PO Box 434, 208 Marshall Street, Warrensburg, MO 64093, qpo1@earthlink.net)

The 113-rank Auditorium organ located in Independence, Missouri, was built by the Aeolian-Skinner Organ Company of Boston, Mass. Immediately after its installation in 1959, the organ became - and remains - perhaps the most important example of the company's work from the period. The commanding display of exposed Great, Positiv, and Pedal pipework forms the visual centerpiece of the massive conference chamber which seats nearly 5,800 people. The main organ is framed by nineteen acoustical clouds suspended above and in front of it, and by choir seating and the large rostrum beneath it. The entire room is covered by a huge dome, culminating in an oculus rising some 100 feet above the floor. G. Donald Harrison, President and Tonal Director of Aeolian-Skinner and one of the twentieth century's most influential organ builders, was responsible for the organ's initial design and specification in the mid-1950s. Following Mr. Harrison's untimely death in 1956, Joseph Whiteford was appointed Tonal Director and, in collaboration with consultants Catharine Crozier and Harold Gleason, finalized the design and formulated the organ's pipe scales. The organ is a superb example of the "American Classic Organ," a concept and design developed by Aeolian-Skinner. (Text by Thomas Brown)

2:40

1pMU6. Acoustics of the pipe organ. Jan Kraybill (Community of Christ Headquarters, 1001 W Walnut St, Independence, KS 64050, jkraybill@CofChrist.org)

An organist's perspective on pipe organ acoustics. The range of frequencies produced by a large pipe organ covers 10 Hz to over 10,000 Hz. Three significant pipe organs in the Kansas City metro area will be discussed: the Julia Kauffman Casavant at the Kauffman Center for the Performing Arts in Kansas City (installation completed early 2012) and the two magnificent instruments at Community of Christ Headquarters in Independence, MO (installations in 1993 and 1959). The acoustic qualities of individual pipes, groups of pipes, and the rooms in which these instruments reside affect the approach which these organs' builders took in designing these one-of-a-kind pipe organs, and the approach each artist takes when making music with them.

Session 1pNS

Noise, Physical Acoustics, Animal Bioacoustics, and ASA Committee on Standards: Outdoor Sound Propagation

Siu-Kit Lau, Cochair
University of Nebraska-Lincoln, Omaha, NE 68182-0816

Kai Ming Li, Cochair
Mechanical Engineering, Purdue University, West Lafayette, IN 47907-2031

Invited Papers

1:00

1pNS1. Excess attenuation and effective impedance associated with rough hard ground. Keith Attenborough, Imran Bashir, and Shahram Taherzadeh (Design, Development, Environment and Materials, The Open University, Walton Hall, Milton Keynes, Buckinghamshire MK7 6AA, United Kingdom, k.attenborough@open.ac.uk)

Although ground effect has been studied widely and is an accepted component of outdoor sound prediction schemes exploitation of ground effect has been restricted to the development of porous road surfaces which influence traffic noise generation as well as propagation. Relatively little attention has been paid to the potential for exploiting the effectively finite impedance associated with roughness small compared with the incident wavelengths on an otherwise acoustically-hard ground or to the potential usefulness of the wide variation in soft ground effects that are available. Results of recent laboratory and field measurements on artificially rough hard surfaces including the comparative acoustical performances of randomly- and periodically-spaced roughness are presented. The laboratory data have been used to study the influences of roughness shape and spacing and surface wave formation. Practical outdoor realisations of artificially roughened hard surfaces have utilised low brick wall configurations and their relative merits have been studied through loudspeaker and car pass by measurements and Boundary Element calculations.

1:20

1pNS2. Estimation of blast noise sound fields over large regions using noise monitors and geostatistical models. Edward T. Nykaza, Michael J. White (US Army Corps of Engineers, Engineer Research and Development Center, 2902 Newmark Drive, Champaign, IL 61822, edward.t.nykaza@erdc.dren.mil), D. Keith Wilson (US Army Corps of Engineers, Engineer Research and Development Center, Hanover, NH), and Anthony A. Atchley (College of Engineering, The Pennsylvania State University, University Park, PA)

This study explores the feasibility of accurately estimating blast noise levels over a large region between and beyond noise monitoring stations using geostatistical models. The potential improvements over propagation modeling include faster computations, fewer assumptions, and improved accuracy. The estimation models explored include kriging, simple interpolation, and models that include meteorological and terrain parameters commonly incorporated into outdoor sound propagation models. The estimation models are evaluated using both experimentally measured and simulated noise monitor data gathered under various atmospheric conditions in several large regions (e.g., greater than 16 km^2). The performance of using geostatistical-based estimation models is discussed in terms of the uncertainty of sound pressure field estimates, sensitivity to atmospheric variability, sensor density and geometry configuration, and model validation.

1:40

1pNS3. Aircraft sound transmission in homes categorized by U.S. climate regions. Erica Ryherd and Nathan Firesheets (Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0405, erica.ryherd@me.gatech.edu)

Current aircraft noise guidelines are based primarily on outdoor sound levels. However, human perception is highly related to indoor response, particularly for residences. A research project is being conducted that provides insight into how typical residential dwelling envelopes affect indoor sound levels. A focus is being placed on non-sonic boom aircraft noise, using continuous noise signatures of commercial aircraft overflights. Typical construction types in various U.S. climate regions have been identified and used to develop model predictions of indoor noise levels. Further, the impacts of systematically altering construction variables such as construction material and window to wall ratio is being investigated. Results will be used to understand trends for expected noise reduction for typical construction types around the U.S.

2:00

1pNS4. Recent advances in sound propagation above a non-locally reacting ground. Kai Ming Li (Mechanical Engineering, Purdue University, 140 South Martin Jischke Drive, West Lafayette, IN 47907-2031, mmkmli@purdue.edu)

In the absence of atmospheric effects, the sound fields above a locally reacting ground can be accurately predicted by the Weyl-van der Pol formula. The solution is based on an asymptotic analysis to yield two terms: a direct and a ground reflected wave terms. The reflected wave term can be written as a product of a spherical wave reflection coefficient and the sound reflected from a rigid ground. In the contrary, it is more challenging to derive a similar formula for the sound fields above non-locally reacting grounds. In the past, an approximation in the same form as the Weyl-van der Pol formula has been used which becomes inadequate for layered grounds. In this presentation, a brief review of the asymptotic analysis will be discussed. An overview of the analytical and numerical approaches will be presented for obtaining accurate prediction of sound fields above the non-locally reacting ground. It will be further demonstrated that the reflection coefficient can be split exactly into two terms - a plane wave reflection coefficient and a ground wave term involving the boundary loss factor. The correlation between the numerical distance and the location of the surface wave pole will be examined.

2:20

1pNS5. A hybrid computational method for computing urban canyon sound fields exhibiting roughness. Carl Hart and Siu-Kit Lau (University of Nebraska - Lincoln, 1110 S 67th St, Omaha, NE 68182, carl.hart@huskers.unl.edu)

Predicting the three-dimensional sound field within an urban canyon is essential for urban noise assessment. Several analytical and computational methods exist to predict the canyon sound field. Generally building facades can be characterized as both geometrically reflecting and dispersive. The image source method is well suited to scenarios where surfaces are geometrically reflecting. Given dispersive surfaces the radiosity method predicts the sound field well. On the other hand a canyon exhibiting geometric and dispersive facades requires a computationally intensive technique such as the finite-element method (FEM) or the boundary-element method (BEM). Due to computational limitations neither the FEM nor BEM are well suited for computing large, unbounded, three-dimensional, urban canyon domains. A prediction method which synthesizes adaptive beam tracing and a secondary model for edge diffraction serves as an alternative technique for analyzing urban canyon acoustics, which contain façades exhibiting both geometric and dispersive surfaces. Advantages of the hybrid method include the ability to model unbounded domains simply, no requirement for discretizing geometric boundaries, and the ability to model sound propagation in the time domain. The magnitude of acoustic dispersion from a surface is related to surface roughness. The effect of surface roughness on the canyon sound field is investigated.

Contributed Papers

2:40

1pNS6. A single-bounce method for estimating impulse propagation and attenuation in a forest. Michelle E. Swearingen (US Army ERDC, Construction Engineering Research Laborartory, P.O. Box 9005, Champaign, IL 61826, michelle.e.swearingen@usace.army.mil) and Donald G. Albert (US Army ERDC, Hanover, NH)

There are numerous methods for determining the impact of interactions with multiple scattering objects on a propagating signal. Many of these methods assume that the signal is continuous in time, allowing one to neglect time dependence. Additionally, these methods make assumptions about the spatial distribution of scattering objects, such as lattice or random, and many assume that the scattering objects are all identical. Real forests often have trees of varying trunk diameters and may be arranged in a grid, in clusters, or random, and the assumptions of uniform size and particular spatial distributions introduce error into the assessments. A simple model, based on single bounces from trunks, is developed to begin estimating the propagation of an impulsive signal through this complicated multiple scattering environment. The scattering algorithm takes the frequency-dependent radial scattering pattern of a cylinder into account. Results are compared to data collected in a forest stand where the locations and diameters of trunks were carefully recorded. These comparisons provide insight into whether a single, discrete bounce method is sufficient for modeling impulse propagation in this complex environment, or whether multiple discrete bounces or some other method should be explored.

2:55

1pNS7. Investigations of measured temperature and wind effects on outdoor sound propagation. Lauren M. Ronsse, Dan Valente, Edward T. Nykaza, and Michael J. White (Construction Engineering Research Laboratory, US Army Engineer Research and Development Center, P.O. Box 9005, Champaign, IL 61826-9005, Lauren.Ronsse@erdc.dren.mil)

Temperature and wind effects on outdoor sound propagation have been well-studied in numerous theoretical investigations, leading to a number of commonly held beliefs about how weather affects outdoor propagation. For example, louder sound levels are expected when downwind propagation and temperature inversions are present, whereas lower levels are expected when upwind propagation and temperature lapses exist. However, the validity of such relationships has not been rigorously tested in the field for various terrains at long distances from an outdoor source. One is justified in questioning the validity of these relationships due to the difficulty of adequately modeling the dynamic atmosphere along the entire propagation path. This study examines some commonly held notions of outdoor sound propagation by experimentally investigating the effects of temperature gradients and wind speed/direction on sound propagation at long distances from a typical impulsive source. Temperature and wind conditions measured near the source and along the line of sound propagation are correlated with the received sound pressure levels recorded at distances up to 15 km from the source. The variability of peak sound pressure levels occurring under similar wind and temperature conditions is assessed, demonstrating that much complexity underlies these common aphorisms.

3:10–3:30 Break

3:30

1pNS8. A modified saddle point method for predicting sound penetration into a rigid-porous ground. Hongdan Tao and Kai M. Li (Purdue University, 140 S. Martin Jischke Drive, West Lafayette, IN 47907, htao@purdue.edu)

An approximate analytical formula has been derived for the prediction of sound penetration into a semi-infinite rigid porous ground due to a monopole source. The sound fields can be expressed in an integral form that is amenable to analytical and numerical analyses. A modified saddle point method is applied to evaluate the integral asymptotically that leads to a closed form expression. The validity of the asymptotic formula is confirmed by comparing with the numerical results computed by the fast field formulation and the direct evaluation of the integral. It has been demonstrated that the present analytical formula is sufficiently accurate to predict the penetration of sound into the semi-infinite rigid porous ground. Furthermore, the sound fields predicted by modified saddle point are compared with that

computed by the double saddle point method. It is found that these two asymptotic schemes give precise solutions at far fields but the modified saddle method is more accurate at the near field especially when both the source and receiver are close to the air/ground interface. [Research is partially funded by the China Research Scholarship Council.]

3:45

1pNS9. Wind noise reduction in a non-porous subsurface windscreen. Allan J. Zuckerwar (Analytical Services and Materials, 1052 Research Drive, Hampton, VA 23666-1340, ajzuckerwar@yahoo.com), Qamar A. Shams, and Keith Knight (NASA Langley Research Center, Hampton, VA)

Measurements of wind noise reduction were conducted on a box-shaped, subsurface windscreen made of closed cell polyurethane foam. The windscreen was installed in the ground with the lid flush with the ground surface. The wind was generated by means of a fan, situated on the ground, and the wind speed was measured at the center of the windscreen lid with an ultrasonic anemometer. The wind speed was controlled by moving the fan to selected distances from the windscreen. The wind noise was measured on a PCB Piezotronics 3" electret microphone. Wind noise spectra were measured with the microphone exposed directly to the wind (atop the windscreen lid) and with the microphone installed inside the windscreen. The difference between the two spectra comprises the wind noise reduction. At wind speeds of 3, 5, and 7 m/s, the wind noise reduction is typically 15 dB over the frequency range 0.1-20 Hz.

4:00

1pNS10. Measurements of acoustic transmission loss over a rough water surface. Cristina Tollefsen and Sean Pecknold (Defence Research and Development Canada - Atlantic, P.O. Box 1012, Dartmouth, NS B2Y 3Z7, Canada, cristina.tollefsen@gmail.com)

Recent interest in understanding acoustic propagation over rough water surfaces has been driven largely by the increasing presence of offshore wind turbines and concerns about the potential for community noise disturbance. In addition, there has been interest in evaluating directional acoustic hailing devices for use at sea, in determining potential environmental impact of naval gunfire exercises, and in understanding the in-air acoustic footprint of maritime-based military assets. Measurements of acoustic transmission loss over a rough water surface were made during the period of 3 Oct and 7 Dec 2011 near Halifax, Nova Scotia, Canada. The acoustic source was a propane cannon, firing four consecutive shots once per hour during daylight hours. A receiver was positioned at ranges of 2 km to 7.5 km from the source, with a clear line-of-sight across the water, for periods ranging from 5-21 days at each location. Temperature, wind velocity, relative humidity, and ocean surface wave height were acquired from a variety of sources, including point measurements, radiosonde profiles, and output from an atmospheric forecasting model (Environment Canada's Global Environmental Multiscale [GEM] model). The measured values of transmission loss are compared to results obtained with a parabolic equation-based atmospheric acoustic propagation model.

4:15

1pNS11. Noise exposure profiles for small-caliber firearms from 1.5 to 6 meters. William J. Murphy (Hearing Loss Prevention Team, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Mailstop C-27, Cincinnati, OH 45226-1998, wjm4@cdc.gov), Gregory A. Flamme (College of Health and Human Services, Western Michigan University, Kalamazoo, MI), Edward L. Zechmann, Caroline Dektas (Hearing Loss Prevention Team, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati, OH), Deanna K. Meinke (Audiology and Speech-Language Sciences, University of Northern Colorado, Greeley, CO), Michael Stewart (Communication Disorders Department, Central Michigan University, Mount Pleasant, MI), James E. Lankford (Allied Health and Communication Disorders, Northern Illinois University, DeKalb, IL), and Donald S. Finan (Audiology and Speech-Language Sciences, University of Northern Colorado, Greeley, CO)

Small caliber firearms (rifles, pistols and shotguns) are commonly used at outdoor firing ranges for training in shooting skills, job qualification and for recreation. Firearm noise from fifty-four weapons was measured at an outdoor range in the near field (6 meters and closer) of the weapons using a radial array of 18 microphones centered on the shooter's head. Each weapon was fired five times and the microphone array was sampled at 200 kHz with at least 16-bit resolution. Peak sound pressure levels and damage risk criteria (e.g. MIL-STD 1474D, 8-hour Equivalent A-weighted Level (LAeq8), and Auditory Hazard Assessment Algorithm for Humans (AHAAH)) were computed for each microphone and compared across weapon type, caliber and load. The acoustic propagation from the muzzle to the microphone was modeled using a simple image source over a reflecting plane. The impedance of the ground was estimated from the observed data and was used to compare the measured waveforms with the estimated waveforms. These data will be used to model the exposures for multiple shooters and observers standing at or behind the firing line.

4:30

1pNS12. Effects of inclusion shapes within rigid porous materials on acoustic performance. Hyun Hong and Siu-Kit Lau (Charles W. Durham School of Architectural Engineering and Construction, University of Nebraska-Lincoln, 1110 S. 67th Street, Omaha, NE 68182, slau3@unl.edu)

The present study investigates the influence of various shapes of inclusions having same volume embedded in a porous rigid material. Previous studies showed improvement of the broadband sound absorption with particular shapes of inclusions. However, different volumes of the inclusions have been considered; therefore, the bulk densities are not the same for comparison. The present study extends the investigations of inclusions in porous materials with same volume (or bulk density) to eliminate the influence by the change of bulk density. The effects of shape will be discussed. Finite element modeling will be used for this study. Total four different shapes: circle, square, ellipse, and triangle, have been studied at various orientations. It has been found that specific configurations can be able to improve the broadband sound absorption compared with reference (no inclusion). It is being expected that a better control of sound absorption of porous materials at desired frequency range can be achieved with the results of the present study.

Session 1pPA

Physical Acoustics and Biomedical Acoustics: Memorial Session for Wesley Nyborg

Lawrence A. Crum, Cochair
Applied Physics Laboratory, University of Washington, Seattle, WA 98105

Junru Wu, Cochair
Physics, University of Vermont, Burlington, VT 05405

Chair's Introduction—1:00

Invited Paper

1:05

1pPA1. Wesley Nyborg and bioacoustics at the University of Vermont. Junru Wu (Physics, University of Vermont, Cook Bldg, Burlington, VT 05405, jwu@uvm.edu)

Wesley Nyborg, Physics Professor Emeritus at the University of Vermont, passed away on September 24, 2011 after a full and wonderful life of 94 years. Wes came to the University of Vermont in 1960 where he did his most pioneering research in microstreaming, acoustic radiation pressure and bioeffects of ultrasound. He was considered as one of most influential pioneers by the international biomedical ultrasound community. Wesley Nyborg has developed an active bioacoustics and biomedical ultrasound research in the university. His research was continuously supported over 20 years by NIH. In this presentation, his research and life with the university will be reviewed.

Contributed Papers

1:25

1pPA2. Wes and Ed and the minus sign—A tale of two giants. Charles C. Church (NCPA, University of Mississippi, 1 Coliseum Drive, University, MS 38677, cchurch@olemiss.edu)

Once upon a time there was a young lad who liked to stroll through the Land of Bioacoustics. It was a pleasant land filled with many things that this fellow found very interesting indeed, but there were also giants. These giants had powerful names like Wes and Ed, and they understood many things that were hidden from the lad. One of these was how to calculate the force exerted by a traveling wave on an object in an acoustic field. With some trepidation, the fellow asked the giants to explain the proper way to make the calculation. "Certainly lad," said Wes, "Here's how to do it." "Oh," said Ed, "but what about this?" Each gave him a paper, and he studied them hard, turning them this way and that, and what did he find? The answers were the same. Well almost. One had a minus sign where the other did not. "I don't understand," said the lad, "How can this be?" "We're really not sure," said the giants, "We'll have to discuss it. We'll tell you tomorrow, or in a month or a year." To learn what they said finally, come to Kansas City to hear.

1:40

1pPA3. Acoustic and optical characterization of ultrasound contrast agents via flow cytometry. Camilo Perez, Andrew Brayman (Center for Industrial and Medical Ultrasound (CIMU), University of Washington Applied Physics Laboratory, 1013 NE 40th Street, Seattle, WA 98105-6698, camipiri@uw.edu), Juan Tu (Key Laboratory of Modern Acoustics, Nanjing University, Nanjing, Jiang Su, China), Jarred Swalwell, Hong Chen, and Tom Matula (Center for Industrial and Medical Ultrasound (CIMU), University of Washington Applied Physics Laboratory, Seattle, WA)

Characterizing ultrasound contrast agents (UCAs) involve measuring the size and population distribution. However, these instruments do not allow for characterization of shell properties, which are important for (1) stability to administration and circulation throughout the vasculature; (2) UCA response to ultrasound; and (3) conjugating ligands for molecular imaging. Thus it is critical to understand the physical and rheological properties of shells. We previously developed a light scattering technique to characterize the shell properties of UCAs [Guan and Matula, JASA, Vol 116(5), 2004; Tu, et al., IEEE Trans. Ultrason., Ferroelec., and Freq. Control, vol. 58(5), 2011]. The most recent manifestation involves a flow cytometer modified with a custom square quartz flow cell in place of the standard nozzle and fluid jet. Acoustic coupling to the carrier sheath fluid and UCA samples occurred through a PZT bonded to one side of the flow cell. The PZT-driven UCA oscillations were processed and fitted to the Marmottant UCA model. Shell properties for UCAs (including Definity, Optison, SonoVue, and even homemade bubbles) were determined. The focus of this talk will be on pressure calibration and additional measurements of unpublished data from Optison and homemade bubbles. (Funded in part by the Life Sciences Discovery Fund #3292512)

1:55

1pPA4. Gauging the likelihood of stable cavitation from ultrasound contrast agents. Kenneth B. Bader and Christy K. Holland (Internal Medicine, University of Cincinnati, 231 Albert Sabin Way, Cincinnati, OH 45267-0586, Kenneth.Bader@uc.edu)

Clinical ultrasound scanners use the Mechanical Index (MI) to gauge the potential for bioeffects due to inertial cavitation. However, the advent of ultrasound contrast agents (UCA) introduces nucleation mechanisms for bubble activity far different than that assumed in the development of the MI. Such exogenous agents promote bubble activity at substantially lower acoustic pressures than those required for inertial cavitation. The onset of this type of gentle bubble activity is within a stable cavitation regime. The minimum thresholds of both stable cavitation (as indicated by the onset of subharmonic oscillations) and the rupture of UCA were numerically calculated as a function of frequency. Both of these thresholds were found to depend linearly on frequency, and a "cavitation index" will be introduced. This index will be compared to the MI and compared to bioeffects studies in the literature. This cavitation index is not intended to replace the MI. Rather, it may be used to gauge the destruction of UCA, or promote bubble activity

to induce beneficial bioeffects mediated by stable cavitation. This work was supported by the National Institutes of Health, grant numbers NIH RO1 NS047603, NIH RO1 HL059586, and NIH RO1 HL74002.

2:10

1pPA5. Engineering tissues with ultrasound heating, radiation force, and cavitation. Diane Dalecki (Biomedical Engineering, University of Rochester, 310 Goergen Hall, P.O. Box 270168, Rochester, NY 14627, dalecki@bme.rochester.edu) and Denise C. Hocking (Pharmacology and Physiology, University of Rochester, Rochester, NY)

Wesley Nyborg was a pioneer in the field of biomedical ultrasound. His theoretical and experimental work forms the foundation for our understanding of the biological effects of ultrasound. He developed fundamental theories of the physical mechanisms of interaction of ultrasound with tissues, including heating, radiation force, and cavitation. In this presentation, we discuss our development of three ultrasound technologies that employ heating, radiation force, or cavitation to address important challenges in tissue engineering. One technology uses radiation forces developed in an ultrasound standing wave field to spatially pattern cells within engineered tissues. The resultant ultrasound-induced patterning can lead to extracellular matrix remodeling, collagen reorganization, and the rapid formation of a vascular network. A second technology uses ultrasound to control the microstructure of collagen within engineered tissues via a thermal mechanism. Through control of ultrasound heating, engineered tissues can be fabricated with spatial variations in collagen microstructures. The structure of extracellular matrix proteins directs cell behaviors important for tissue formation. In the third technology, ultrasound is used to alter the conformation of another extracellular matrix protein, fibronectin, likely through a cavitation mechanism. These studies highlight how fundamental principles of ultrasound-tissue interactions can be used to develop novel tools for tissue engineering.

2:25–3:10 Break

3:10

1pPA6. Nucleating and sustaining acoustic cavitation for biomedical applications. Tyrone M. Porter (Mechanical Engineering, Boston University, 110 Cummington St, Boston, MA 02215, tmp@bu.edu)

Wes Nyborg was a pioneer in the field of biomedical ultrasound. In particular, Nyborg conducted extensive studies that provided insight into how bubbles oscillating in liquids generated forces that could alter the anatomy and/or physiology of cells. While these studies demonstrated that acoustic cavitation is instrumental in a variety of bioeffects, nucleating and sustaining acoustic cavitation in a controlled manner has proven to be a challenge, particularly in vivo. Studies have shown that these challenges can be addressed with the use of novel materials, particles, and/or acoustic pulsing schemes. In particular, pH-sensitive polymers with varying hydrophobicity have been used to sustain cavitation/cell interactions and vaporizable perfluorocarbon nanoemulsions have been used to reduce the pressure threshold for cavitation nucleation. The impact of these materials and particles on cavitation-mediated bioeffects will be discussed.

3:25

1pPA7. Tracking the motion of cavitation bubbles using pulsed Doppler. E. C. Everbach (Engineering, Swarthmore College, 500 College Avenue, Swarthmore, PA 19081, ceverba1@swarthmore.edu)

Echo-contrast agent microbubbles in blood can sometimes penetrate a clot that is blocking bulk flow in the vessel. When ultrasound is applied for the purpose of sonothrombolysis, microbubbles can be forced by acoustic radiation force into the clot matrix. To monitor the extent of this penetration, a 20 MHz pulsed Doppler method was employed to measure both the position of the bubble front in the clot and its velocity. Correlations between clot dissolution and the location of the advancing microbubble front may be used to optimize cavitational activity and improve sonothrombolysis.

3:40

1pPA8. Recent advances concerning acoustic radiation forces and torques and Wes Nyborg's helpful discussion of acoustic streaming. Philip L. Marston, L. K. Zhang, and David B. Thiessen (Physics and Astronomy Dept., Washington State University, Pullman, WA 99164-2814, marston@wsu.edu)

Recent theoretical advances concerning the geometrical interpretation of acoustic radiation forces [L. K. Zhang and P. L. Marston, Phys. Rev. E 84, 035601R (2011); L. K. Zhang and P. L. Marston, J. Acoust. Soc. Am. 131, EL329-EL335 (2012)] and the scaling of acoustic radiation torques for symmetric objects in beams and in standing waves with increasing helicity [L. K. Zhang and P. L. Marston, Phys. Rev. E 84, 065601R (2011)] will be summarized. For spheres in beams it has been possible to find situations giving transversely stable radiation forces using finite elements. The predicted scaling properties of acoustic torques have been verified in an investigation by an independent group [C. E. M. Demore et al., Phys. Rev. Lett. 108, 194301 (2012); A. G. Smart, Physics Today 65 (6), 18-20 (2012)]. This work will be examined in the context of broader discussions with, and/or a few of the interests of, Wes Nyborg and his practical analysis of acoustic streaming [W. L. Nyborg, in Nonlinear Acoustics, edited by M. F. Hamilton and D. T. Blackstock (Academic Press, San Diego, CA, 1998)] pp. 207-231. [Marston and Thiessen were supported in part by ONR. Zhang was supported in part by NASA.]

3:55

1pPA9. Acoustic streaming in therapeutic ultrasound. Lawrence A. Crum (Applied Physics Laboratory, University of Washington, 1013 NE 40th Street, Seattle, WA 98105, lac@apl.washington.edu)

Wesley Nyborg's contributions to a theoretical description of acoustic streaming were pioneering, rigorous, and so thorough that little additional work has been published. Acoustic streaming has had many applications in acoustics, especially medical acoustics, in which it is difficult to avoid. In many cases, it can be used to enhance or accelerate a particular therapeutic effect. This presentation will provide a few examples of the role of acoustic streaming in therapeutic ultrasound as well as share a few warm memories of this kind and generous man. [Work supported in part by the NIH and NSBRI.]

4:10–4:40 Panel Discussion

Session 1pUW

Underwater Acoustics: Reverberation and Scattering

John R. Preston, Chair
ARL, Pennsylvania State Univ., State College, PA 16804

Contributed Papers

2:30

1pUW1. Planning for a reverberation field experiment. Dajun Tang, Brian T. Hefner, Kevin L. Williams, Jie Yang, and Eric I. Thorsos (Applied Physics Lab, Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, djtang@apl.washington.edu)

A basic research reverberation experiment, supported by the US Office of Naval Research, is planned for 2013. Measurement issues that arise when planning such an experiment are discussed. The fundamental requirement for this basic research experiment is that the environment is characterized in sufficient detail to allow accurate numerical modeling of the acoustical results based on the environmental description. The main goal is to measure mid-frequency shallow water reverberation with full companion environmental measurements so that model/data can be compared without ambiguity. Included in the goal is to make statistical estimates of the uncertainties associated with all the environmental conditions. The frequency range of interest is 1-10 kHz with emphasis at 3 kHz. A pilot field experiment was conducted off the coast of Panama City, Florida. Data from the pilot experiment will be discussed in light of the forthcoming main experiment, including simulations on both propagation/forward-scatter and reverberation for given noise background on both vertical and horizontal arrays which will be deployed in the main experiment.

2:45

1pUW2. Scattering enhancements for partially exposed cylinders at a free surface caused by Franz waves: Measurements and geometric model. Grant C. Eastland and Philip L. Marston (Physics and Astronomy Dept., Washington State University, Pullman, WA 99164-2814, marston@wsu.edu)

Creeping waves on solid cylinders having slightly subsonic phase velocities and large radiation damping are usually described as Franz waves because of their association with complex poles investigated by Franz. For free-field high frequency broadside backscattering in water, the associated echoes are weak due to the radiation damping. It is demonstrated here, however, that for partially exposed solid metal cylinders at a free surface viewed at grazing incidence, the Franz wave echo can be large relative to the specular echo even for ka above 20 when the grazing angle is sufficiently small. The reason is that at small grazing angles and small exposures, the Fresnel zone associated with the specular echo is occluded so that the specular echo is weak [K. Baik and P. L. Marston, IEEE J. Ocean. Eng. 33, 386 (2008)] while the Franz wave is partially reflected at the interface. This has been confirmed from the evolution of echo timing with cylinder exposure and by SAS imaging. In the experiment a solid cylinder was slowly lowered through the free surface into the water. In bistatic scattering a Franz echo can be present with small exposure without the Franz wave reflecting from the free surface. [Supported by ONR.]

3:00

1pUW3. Computation of backscattering enhancements by a half-exposed rigid cylinder at a free surface caused by Franz waves. Anthony R. Smith, Daniel S. Plotnick, Grant C. Eastland, and Philip L. Marston (Physics and Astronomy Dept., Washington State University, Pullman, WA 99164-2814, marston@wsu.edu)

Recent observations of the backscattering by partially-exposed solid aluminum cylinders in water viewed at grazing incidence at a free surface [G. C. Eastland, Ph.D. thesis, Wash. State Univ., 2012] indicate that the generation, propagation, and reflection of Franz-type creeping waves can be important. The present investigation gives additional support for this hypothesis by calculating the exact backscattering by a half-exposed infinitely long rigid cylinder viewed over a range of grazing angles. The calculation begins with the known frequency domain expression for the complex amplitude given in an Appendix of [K. Baik and P. L. Marston, IEEE J. Ocean. Eng. 33, 386 (2008)]. Numerical Fourier transforms were used to construct the time-domain response for various excitations and the evolution of that response was investigated as a function of the grazing angle. This procedure reveals from the timing of the computed features there is a significant delayed echo having the expected timing of a Franz wave partially reflected from the free surface. The timing of the Franz wave depends on grazing angle in agreement with a geometric model in Eastland's thesis. [Supported by ONR.]

3:15

1pUW4. Some initial findings from the very shallow water GulfEx12 reverberation experiments. John R. Preston (ARL, Penn State Univ., P.O. Box 30, MS3510, State College, PA 16804, jrp7@arl.psu.edu)

In April 2012, reverberation and clutter measurements were taken in very shallow water (~20 m) over a 40 hour period off Panama City, FL. This work describes the data from this recent sea trial called GULFEX12 designed to characterize reverberation and clutter from a very shallow water site in the 2500-5500 Hz band. The received data are taken from one aperture of the Five Octave Research Array (FORA) namely, the triplet subaperture. The array was fixed 2 m off the sea floor by mounting it to tripods using a clothes line and data were passed by cable to a nearby moored ship (the R/V Sharp). An ITC source transducer was located 3 m away from the array center. Data show a surprising amount of anisotropy. Five different pulses were used in this study. Matched filtered polar plots of the reverberation and clutter are presented using the FORA triplet beamformer to map out anisotropy. Some model data comparisons are made using the author?s normal mode based reverberation model. Help from D.J. Tang, T. Hefner and K. Williams of Applied Physics Lab at Univ. of Washington was crucial to this effort. [Work supported by ONR code 322OA.]

3:30

1pUW5. Scattering of low-frequency spherical waves by fluid and solid spheres. Oleg A. Godin (CIRES, Univ. of Colorado and NOAA Earth System Research Laboratory, Physical Sciences Div., Mail Code R/PSD99, 325 Broadway, Boulder, CO 80305-3328, oleg.godin@noaa.gov)

Acoustic Green's functions for a homogeneous fluid with an embedded spherical obstacle arise in analyses of sound scattering by air bubbles, scattering by objects on or near the seafloor, radiation by finite sources, sound attenuation in and scattering from clouds of suspended particles, etc. Here, radius of the obstacle is assumed to be small compared to the wavelength of sound. This regime is usually referred to as Rayleigh scattering. A new, elementary solution of the problem of diffraction of a spherical wave was recently obtained for small, soft obstacles [O. A. Godin, J. Acoust. Soc. Am. **37**, L13605 (2010)]. The solution is valid for arbitrary positions of the source and receiver relative to the obstacle. In this paper, the solution is extended to homogeneous and inhomogeneous fluid and solid spheres. Low-frequency scattering is found to be rather sensitive to boundary conditions on the surface of the obstacle. Resonance scattering of spherical waves by small spheres is investigated. [Work supported, in part, by ONR.]

3:45

1pUW6. Fast model for target scattering in a homogeneous waveguide. Steven G. Kargl, Kevin L. Williams, and Aubrey L. Espana (Applied Physics Laboratory, University of Washington, 1013 NE 40th St, Seattle, WA 98105, kargl@apl.washington.edu)

A fast ray model for propagation in a homogenous water column tracks time-of-flight wavepackets from sources to targets and then to receivers. The model uses image sources and receivers to account for interactions with the water column boundaries, where the layer of water lies between an upper semi-infinite halfspace of air and a lower semi-infinite halfspace of a homogenous sediment. The sediment can be either an attenuating fluid with a frequency-independent loss parameter or a fluid consistent with an effective density fluid model (i.e., a fluid limit to Biot's model for a fluid-saturated poroelastic medium). The target scattering process is computed via convolution of a free-field scattering form function with the spectrum of an incident acoustic field at the target location. A simulated or measured scattered free-field pressure from a complicate target can be reduced to a scattering form function, and this form function then can be used within model via interpolation. The fast ray-based model permits the generation of sets of realistic pings suitable for synthetic aperture sonar processing for proud and partially buried target. Results from simulations are compared to measurements where the targets are an inert unexploded ordnance and aluminum cylinder. [Research supported by SERDP and ONR.]

4:00

1pUW7. Supervised machine learning for classification of underwater target geometry from sampled scattered acoustic fields in the presence of rough bottom interference. Erin M. Fischell and Henrik Schmidt (Mechanical Engineering, MIT, 77 Massachusetts Ave., Cambridge, MA 02139, emf43@mit.edu)

An increasingly important mission for Autonomous Underwater Vehicles (AUVs) is the identification and classification of potentially hazardous targets in harbors. A process is demonstrated in simulation that would allow AUV in-flight classification of spherical and cylindrical targets using only scattered acoustic amplitudes collected at waypoints. Target and bottom roughness scattered fields are simulated using OASES and SCATT, then combined and sampled into independent training and testing examples for a Support Vector Machine (SVM). The feature space and parameters for the SVM are selected using a design of experiments grid search. By processing the model using a feature reduction algorithm, it is possible to identify the regions in the scattered field that are the most critical for classification. To make use of the resulting models and critical features, a vehicle in the field would be loaded with pre-generated models for bottom and target classification. Upon target localization, the vehicle would begin visiting the critical waypoints until a confident classification is achieved using the SVM models. The resulting in-flight classification, based only on amplitude data collected by a hydrophone along the vehicle's path, could be used as the basis for further action on the target. [Work supported by ONR and NSF GRFP.]

4:15

1pUW8. Simulating coherent backscatter enhancement from aggregations of underwater scatterers. Adaleena Mookerjee and David R. Dowling (Mechanical Engineering, University of Michigan, Ann Arbor, MI 48105, adaleena@umich.edu)

Remote classification of scatterers is an enduring priority in active sonar applications. For aggregations of marine life, typically schools or shoals of fish, remote classification may be possible when there is coherent backscattering enhancement (CBE) from the aggregation. CBE is a multiple scattering phenomenon that occurs in optics and acoustics when wave propagation paths within the aggregation are likely to be traversed in both directions. For a plane wave illuminating a half-space of randomly-placed, omnidirectional scatterers, CBE may lead to a doubling of the scattered field intensity in the direction opposite that of the incident wave (Akkermans et al. 1986). This presentation describes acoustic CBE simulations for finite-size spherical aggregations of point scatterers. The results are developed from the classical multiple-scattering equations of Foldy (1945), and are checked to ensure appropriate rotational symmetries and acoustic energy conservation when scatterer locations are random and when they are structured. Variations in the magnitude of the CBE peak and its angular width are presented for different frequencies, aggregation sizes, scatterer densities, and scatterer properties. Extension of these results to sonar-pulse scattering from schools of fish will be discussed. [Supported by the Office of Naval Research.]

4:30

1pUW9. Frequency response of ordnance replicas across multiple scales. Christopher Dudley, Jermaine Kennedy, Kwang Lee, and David Malphurs (Naval Surface Warfare Center, Panama City Division, 110 Vernon Ave, Panama City, FL 32407, mhhd@hotmail.com)

Broad-band, multi-aspect backscatter data obtained using small-scaled and full-scaled replicas of Unexploded Ordnance (UXO) are reported. Data were collected using either linear or circular rail systems. The experiments were performed in: (1) NSWC PCD's small scale test bed (less than 1/16 scaled) which has a simulated bottom, (2) NSWC PCD's Facility 383 9-million gallon fresh water test pool which has a 5-ft sand bottom, and (3) the Gulf of Mexico during GULFEX12 off Panama City, Florida. Data were processed using linear and circular synthetic aperture sonar techniques to generate both images and plots of target strength as functions of frequency and aspect angle. The results from all three experiments are compared to each other and with predictions from Finite-element (FE) analysis. These comparisons are used to assess the utility of alternative methods for generating sonar data from bottom targets of sufficient fidelity to study scattering phenomena and support development of automated target recognition. [Work supported by ONR Code 32 and SERDP.]

Payment of additional registration fee required to attend. See page A?

MONDAY EVENING, 22 OCTOBER 2012 COLONIAL, 7:00 P.M. TO 9:00 P.M.

Session 1eID

Interdisciplinary: Tutorial Lecture on the Acoustics of Pianos

James P. Cottingham, Chair
Physics, Coe College, Cedar Rapids, IA 52402

Chair's Introduction—7:00

Invited Paper

7:05

1eID1. The acoustics of pianos. Antoine J. Chaigne (ENSTA, UME, Chemin de la Huniere, Palaiseau, 91761, France, antoine.chaigne@ensta-paristech.fr)

The manufacturing of pianos remains largely empirical, with numerous trial-and-error procedures and fine adjustments at each step of the building process. The "skeleton" of the instrument obeys fundamental principles of vibrations, acoustics, and material science. An abundance of literature is available on its different constitutive parts. However, scientific studies based on a global model of the instrument that connects all of these constitutive parts together are more recent. Such modeling sheds useful light on the essential coupling properties between elements and, in particular, on the string-soundboard coupling at the bridge, and on the radiation of the soundboard. Fine analysis of piano tones also shows that in most cases, a nonlinear model of the strings is necessary to account for perceptually significant features such as precursors in the time-domain and the so-called "phantom partials" in the spectrum. This nonlinearity is based on the coupling between transverse and longitudinal waves in the string. In this lecture, a time-domain model of a complete piano is presented that couples together nonlinear strings, soundboard vibrations, and radiation in air. It highlights the transmission of both transverse and longitudinal string forces to the soundboard, and the influence of rib design and bridge on soundboard mobility and radiation patterns. Comparisons between the results of the model and measurements made on real pianos will be discussed.