Session 2pAAa

Architectural Acoustics and the National Council of Acoustical Consultants: Student Design Competition

Robert D. Coffeen, Cochair
Univ. of Kansas, 134 Marvin Studios, Lawrence, KS 66045

Byron W. Harrison, Cochair
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The Technical Committee on Architectural Acoustics of the Acoustical Society of America, the National Council of Acoustical Consultants, and the Robert Bradford Newman Student Award Fund are sponsoring the 2007 Student Design Competition that will be professionally judged at this meeting. The purpose of this design competition is to encourage students enrolled in architecture, engineering, physics, and other university curriculums that involve building design and/or acoustics to express their knowledge of architectural acoustics in the design of a music performance hall and related facilities that will be used primarily for a college opera program. This competition is open to undergraduate and graduate students from all nations. Submissions will be poster presentations that demonstrate room acoustics, noise control, and acoustic isolation techniques in building planning and room design. The submitted designs will be displayed in this session and they will be judged by a panel of professional architects and acoustical consultants. An award of $1250.00 US will be made to the entry judged ''First Honors.'' Four awards of $700.00 US will be made to each of four entries judged ''Commendation.''

TUESDAY AFTERNOON, 5 JUNE 2007 CANYON A, 4:00 TO 5:00 P.M.

Session 2pAAb

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

Lily M. Wang, Chair
Univ. of Nebraska, Lincoln, Architectural Engineering, 101A Peter Kiewit Inst., 1110 S. 67th St., Omaha, NE 68182-0681

Chair's Introduction—4:00

Invited Paper

4:05

2pAAb1. The soundscape of modernity: Architectural acoustics and the culture of listening in America, 1900–1933. Emily Thompson (Dept. of History, Princeton Univ., 136 Dickinson Hall, Princeton NJ 08544-1174, emilyt@princeton.edu)

The American soundscape changed dramatically during the early decades of the twentieth century as new acoustical developments transformed both what people heard and the ways that they listened. What they heard was a new kind of sound that was the product of modern technology. They listened as newly critical consumers of aural commodities. Reverberation equations, sound meters, microphones, and acoustical tiles were deployed in places as varied as Boston's Symphony Hall, New York's office skyscrapers, and the sound stages of Hollywood. The result was that the many different spaces that constituted modern America began to sound alike—clear, direct, efficient, and non-reverberant. While this new modern sound said little about the physical spaces in which it was produced, it has much to tell us about the culture that created it. This talk will explore the history of modern sound and modern culture in early twentieth-century America.

Session 2pAB

Animal Bioacoustics: Seismic Communication in Animals

Peggy Hill, Cochair
Univ. of Tulsa, 600 S. College, Tulsa, OK 74104

Caitlin O'Connell-Rodwell, Cochair
Stanford Univ., Dept. of Otolaryngology, Head & Neck Surgery, 801 Welch Rd., Stanford, CA 94305

Invited Papers

1:00

2pAB1. A snapshot of known animal communication via the vibration channel. Peggy Hill (Faculty of Biological Sci., The Univ. of Tulsa, 600 South College, Tulsa, OK 74104, peggy-hill@utulsa.edu)

When a new field, or sub-discipline, first emerges in the scientific arena, terminology is often borrowed from mostly compatible and closely related fields, or those fields from which the new one is emerging. Jargon is employed within the new field when the established vocabulary fails. A point is reached when the best interest of communication with those outside the new field requires development of a new vocabulary, or at least a specific redefinition of broadly used terms, so that the new field can continue to develop and fill its own niche. Animals from fiddler crabs to elephants communicate via the vibration channel. In fact, when researchers have suspected substrate borne signaling, it has almost always been confirmed. In this presentation, I will provide examples from the literature of animals across taxa that are known to communicate in this way, and the contexts within which signals are sent and received. Further, I will pose questions (with few answers) concerning selection for use of the channel, along with examples of instances where changes in the use of terminology over a couple of decades has restricted access to early work in this field.

1:30

2pAB2. Host shifts and the evolution of vibrational communication in treehoppers. Reginald B. Cocroft (Biological Sci., Univ. of Missouri, Columbia, MO 65211, CocroftR@missouri.edu)

Speciation in plant-feeding insects is associated with shifts to novel host plants. Along with differences in a suite of life history and fitness-related traits, closely related insect species that live on different host plants often differ dramatically in their communication systems. Differences in traits involved in sexual communication can provide a source of reproductive isolation and thereby facilitate speciation. Here the relationship between host shifts and changes in sexual communication is investigated in a group of host-specialist insects, the *Enchenopa binotata* species complex of treehoppers (Hemiptera: Membracidae). Each of the eleven species in the complex has unique plant-borne signals used in the process of pair formation. Variation between species in female preferences and male signal traits indicates that closely-related species on different host plants have experienced divergent sexual selection. Changes in host use can also promote signal evolution through divergent natural selection on signal form and through phenotypic plasticity. Host shifts can thus have multiple effects on the evolution of communication systems in plant-feeding insects. [Work support for this research was provided by NSF.]

2:00

2pAB3. Changes in host plant use favor divergence of vibrational signals in treehoppers (Membracidae: *Enchenopa binotata*). Gabriel D. McNett and Reginald B. Cocroft (Div. of Biological Sci., Univ. of Missouri, Columbia, 105 Tucker Hall, Columbia, MO 65211, gdmgw3@mizzou.edu)

Shifts to novel host plants can have dramatic consequences for a wide range of traits in plant-feeding insects. If the traits affected are mating signals, host shifts can provide a direct source of reproductive isolation. Mating signal evolution will be affected when changes in host use, either by use of a different plant species or plant part, lead to communication in a different signal environment. The sensory drive hypothesis predicts that signals should adapt to transmit efficiently in their local environment. Signal divergence, therefore, can occur where closely related insect species occur on host plants with different signal transmission properties. These predictions were tested in two closely related species in the Enchenopa binotata species complex (Hemiptera: Membracidae), host-specific plant-feeding insects that communicate using plant-borne vibrations. Their mating signals are relatively pure tones that vary among species in frequency (pitch), the most important signal trait for mate recognition. As predicted by sensory drive, it is shown that two closely related *E. binotata* species have evolved signals that transmit most efficiently in their contrasting communication environments. Changes in host use thus favor divergence of the signal trait most important for behavioral isolation. [Work supported by NSF.]

2:30

2pAB4. Strategies for seismic signal communication in spiders. Damian O. Elias, Andrew C. Mason (Dept. of Life Sci., Univ. of Toronto at Scarborough, 1265 Military Trail, Scarborough, ON M1C 1A4, Canada, elias@utsc.utoronto.ca), and Eileen A. Hebets (Univ. of Nebraska, Lincoln, NE 68588)

Communication is often hypothesized to be optimally designed for its specific signaling environment. While empirical studies have demonstrated this in several systems, the effect of high channel availability and heterogeneity has not been explored. Seismic (vibratory) communication presents a potential sender with a variety of potentially distinct signaling channels. Using examples from two types of spiders (*Salticidae* and *Lycosidae*), it is demonstrated that small animals use one of two strategies. Animals can be either: (1) specialized to the properties of a particular subset of signaling channels (narrow band signals) or (2) general to all signaling channels (broadband signals). Tradeoffs are discussed as well as the mate choice patterns associated with these different strategies. [Funding was provided by the National Science Foundation, the Natural Sciences and Engineering Council, and a Sigma Xi Society Grant-in-Aid.]

3:00-3:15 Break

3:15

2pAB5. Vibrational information in two life stages of the red-eyed treefrog: Agonistic communication signals and predation risk cues in an arboreal environment. Michael S. Caldwell, Karen M. Warkentin (Dept. of Biol., Boston Univ., 5 Cummington St., Boston, MA 02215), and J. Gregory McDaniel (Boston Univ., Boston, MA 02215)

Red-eyed treefrogs form dense mating aggregations and lay eggs in vegetation over neotropical ponds. Seismic information serves two important behavioral roles for this species. Adult males communicate with seismic signals during agonistic interactions, and embryos detect predators using vibrational cues. Males defending calling sites rapidly extend and contract their hindlimbs, shaking their bodies and the plant in tremulatory displays. This generates strong stereotyped substrate vibrations (12 ± 0.4 Hz, constant amplitude) that propagate to other males. Temporal, amplitude, and frequency properties of this signal are all distinct from common background vibrations and, in videotaped interactions, tremulation vibrations appear behaviorally relevant. In contrast, embryos experience predator and benign-source vibrations that overlap in temporal, amplitude, and frequency properties. These vibrations first pass through the gelatinous egg clutch and are shaped by its physical properties. Modal analysis indicates that natural free vibration frequencies of clutches are low (fundamental: 17 ± 2 Hz); these dominate both benign and dangerous direct disturbances. Additionally, the clutch acts as a frequency filter, rapidly attenuating energy over 200 Hz. Comparing the red-eyed treefrogs use of seismic information in communication and predator detection reveals the different requirements for perceptual strategies employing stereotyped and non-stereotyped information, and furthers our understanding of the seismic modality.

3:45

2pAB6. Vibrational risk assessment as a signal detection problem: Escape hatching of red-eyed treefrog eggs. Karen M. Warkentin, Michael S. Caldwell (Dept. of Biol., Boston Univ., 5 Cummington St., Boston, MA 02215, kwarken@bu.edu), and J. Gregory McDaniel (Boston Univ., Boston, MA, 02215)

The properties of cues from predators often overlap with background stimuli. Thus, prey may make two errors when assessing risk. They may miss cues and fail to defend themselves, or respond unnecessarily to false alarms. Although the incidence of these errors trades off, total error rates can be reduced only by adding information, either through increased sampling of one property or by sampling more cue properties. Adding cue properties likely increases processing requirements, and sampling predator cues entails risk. We examined a vibration-cued defense of the arboreal embryos of red-eyed treefrogs. These embryos use vibrations in snake attacks to cue behaviorally-mediated premature hatching and escape, but vibrations from benign sources rarely induce premature hatching. Missed cues and false alarms are costly; embryos that fail to hatch are eaten, and hatching prematurely increases predation by aquatic predators. Vibration playback experiments indicate that embryos attend to at least four nonredundant properties of vibrations: duration, spacing, stimulatory low frequencies, and inhibitory higher frequencies. They also adjust the amount of information they sample prior to hatching based on the time/risk cost of gathering it. This complexity of the risk assessment mechanism is consistent with strong selection against both missed cues and false alarms.

4:15

2pAB7. The vibration sense in large mammals and its role in communication: Elephants as a case study. Caitlin E. O'Connell-Rodwell (Dept. of Otolaryngol., Head & Neck Surgery, Stanford Univ., Stanford, CA 94305)

All mammals have the ability to detect vibrations and there are some notable cases of small mammals dedicating much of their sensory world to vibration detection such as the star nosed mole, the golden mole, the blind mole rat. In large mammals, the concept of using vibrations as a form of prey detection, predator avoidance, or communication has not been explored to a great extent. A few cases of these three uses of vibrations will be reviewed as they pertain to and may benefit the lion, kangaroo, and elephant seal, respectively. Elephants are well suited to communicate seismically, given their high amplitude, low frequency vocalizations that couple with and propagate in the ground as seismic signals. A unique combination of anatomical structures found on the elephant

would also facilitate seismic detection through either a bone conducted or somatosensory pathway, or both. A series of studies will be reviewed demonstrating the elephants ability to generate and propagate seismic energy from vocalizations and footfalls as well as their ability to detect and discriminate not only biologically meaningful seismic cues from noise, but also subtle differences between seismic vocalizations given in the same context.

4:45

2pAB8. Methods for studying seismic communication in elephants and other large mammals: Arrays, census techniques and more. Jason D. Wood, Caitlin E. O'Connell-Rodwell, Sunil Puria (Stanford Univ., Dept. of Otolaryngol.—Head and Neck Surgery, 801 Welch Rd., Stanford, CA 94305-5739), and Simon L. Klemperer (Stanford Univ., Stanford, CA 94305-2215)

Studying seismic communication poses unique methodological challenges. Methods for producing and monitoring seismic signals will be presented in the context of elephant seismic playback studies as well as large mammal footfall recordings for the purpose of censusing populations remotely. The use of multiple sensors in an array allows for a number of analyses to be conducted to determine the propagation of the signal. Specifically, arrays allow for the measurement of wave velocity and attenuation as well as determination of the mode of propagation. In addition, time of arrival differences can also be used to estimate the source of the signal which has important implications for measuring signal attenuation and in using seismic cues to estimate the number of animals in a group. One challenge in seismic playback studies is to ensure that there is no acoustic coupling of the seismic signal playback, the presence of which would make it impossible to rule out that any behavioral reactions of the study species are due to the acoustic signal that has leaked from the substrate. Matched filtering techniques have been used to detect any playback signal in the acoustic recording of the playback.

TUESDAY AFTERNOON, 5 JUNE 2007 SEMINAR THEATER, 1:00 TO 3:15 P.M.

Session 2pBBa

Biomedical Ultrasound/Bioresponse to Vibration: Therapeutic Ultrasound and Bioeffect

John S. Allen, III, Chair

Univ. of Hawaii, Dept. of Mechanical Engineering, Holmes Hall Room 302, 2540 Dole St., Honolulu, HI 96822

Contributed Papers

1:00

2pBBa1. Bubble proliferation in shock wave lithotripsy. Yuri A. Pishchalnikov, James A. McAteer (Dept. of Anatomy and Cell Biol., School of Medicine, Indiana Univ., 635 Barnhill Dr., Indianapolis, IN 46202-5120, yura@anatomy.iupui.edu), Michael R. Bailey (Univ. of Washington, Seattle, WA 98105-6698), James C. Williams, Jr. (Indiana Univ., Indianapolis, IN 46202-5120), and Oleg A. Sapozhnikov (Moscow State Univ., Moscow 119992, Russia)

Stone breakage is less efficient when lithotripter shock waves (SWs) are delivered at 2 Hz compared to slower 0.5–1-Hz pulse repetition rates (PRFs). This correlates with increased number of transient cavitation bubbles observed along the SW path at fast PRF. The dynamics of this bubble proliferation throughout the bubble lifecycle is investigated in this report. Cavitation bubbles were studied in the free-field of a shock wave lithotripter using fine temporal and microscopic spatial resolution (high-speed camera Imacon-200). A typical cavitation bubble became visible (radius$>10\ \mu$m) under the tensile phase of the lithotripter pulse, and at its first inertial collapse emitted a secondary SW and formed a micro-jet, which then could break up forming $\sim$25 micro-bubbles. Subsequent rebound and collapse of the parent bubble appeared to produce a further 40–120 daughter bubbles visible following the rebound. Preexisting bubbles hit by the lithotripter SW also formed micro-jets and broke up into micro-bubbles that grew and coalesced, producing irregular-shaped bubbles that, in turn, broke into micro-bubbles upon subsequent inertial collapse. A conventional NTSC-rate camcorder was used to track cavitation bubbles from pulse-to-pulse, showing that a single bubble can give rise to a cavitation cloud verifying high-speed video results. [Work supported by NIH-DK43881.]

1:15

2pBBa2. Blood mimicking fluid for high-intensity focused ultrasound applications. Yunbo Liu, Subha Maruvada, Keith A. Wear, Bruce A. Herman (Food and Drug Administration, Ctr. for Devices and Radiological Health, 9200 Corporate Blvd., M.S. HFZ-170, Rockville, MD 20850), and Randy L. King (Stanford Univ., Stanford, CA 94305)

A blood-mimicking fluid (BMF) having viscosity, attenuation, and backscatter similar to that of human blood has been developed for the acoustic and thermal characterization of HIFU ablation devices. The BMF consists of gellan gum, low density polyethelene particles, and nylon particles dispersed in water, glycerin, and alcohol. The BMF was characterized for attenuation coefficient, speed of sound, backscatter coefficient, viscosity, thermal diffusivity, and thermal conductivity. The low attenuation as well as the sound speed and the bloodlike backscatter indicate the usefulness of the BMF for ultrasound imaging and flow applications. These properties, along with thermal conductivity and diffusivity also within the range found in human tissue and the ability to withstand temperature increases above 70 °C with no significant change in its properties, make this material appropriate for HIFU applications. This fluid also ex-

hibits viscosity varying as a function of velocity (or shear rate). [This research was supported by the Defense Advanced Research Projects Agency (DARPA) through IAG No. 224-05-6016.]

1:30

2pBBa3. Formation of shock waveforms and millisecond boiling in an attenuative tissue phantom due to high-intensity focused ultrasound.

Michael S. Canney, Michael R. Bailey, Vera A. Khokhlova, and Lawrence A. Crum (Ctr. for Industrial and Medical Ultrasound, Appl. Phys. Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105)

Nonlinear propagation effects during high-intensity focused ultrasound (HIFU) treatments can induce shocks in the acoustic waveform, dramatically accelerate heating rates, and result in rapid boiling of tissue at the focus. Localized boiling can be used for targeting and calibration of clinical HIFU treatments. In our previous work, millimeter size boiling bubbles were observed in several milliseconds in a weakly absorptive transparent tissue phantom, and temperature rise to 100 °C was calculated using weak shock theory from experimentally measured and numerically simulated focal waveforms [Canney *et al.*, J. Acoust. Soc. Am. **120**, 3110 (2006)]. In this work, experiments are extended to an opaque phantom that has higher attenuation (0.5 dB/cm/MHz in the new phantom versus 0.15 dB/cm/MHz in the previous one) more similar to real tissue. Focal acoustic waveforms are measured using a fiber optic probe hydrophone and time to boil is monitored using a 20-MHz acoustic detector. Modeling of experimental conditions is performed with a KZK-type numerical model. Results demonstrate that although higher source amplitude is needed to attain the same focal amplitudes in the new, more attenuative phantom, similar amplitude shocks can be formed, resulting in equally fast heating rates. [Work supported by NIH DK43881 and NSBRI SMS00402.]

1:45

2pBBa4. Parametric study of a shape based inversion for detecting high-intensity focused ultrasound lesions.

Bruno Durning (Elec. and Comput. Eng., Northeastern Univ., Boston MA 02115), Robin O. Cleveland (Boston Univ., Boston MA, 02215), and Eric L. Miller (Tufts Univ., Medford, MA 02155)

A key problem in the practical use of high intensity focused ultrasound (HIFU) as a tool for cancer treatment is the non-invasive characterization of the regions of tissue that have successfully been necrosed. Previously, we proposed an approach to image guidance, based on the use of RF data obtained from a diagnostic ultrasound transducer and a shape-based inverse scattering approach. Specifically, it was assumed that the lesion has an ellipsoidal shape defined by its center, size, orientation, and contrast (in sound-speed and attenuation) compared to the background. An inverse-type method was used to identify the ellipsoid parameters from the RF data. In this work we explore the robustness of this approach to a variety of conditions likely to be encountered in practice, specifically, the presence of an aberatting layer in the path, the formation of non-ellipsoidal lesions, for example, a ''tadpole'' shaped lesion that is commonly formed during HIFU, and the presence of multiple objects. Experiments using a clinical scanner and tissue phantoms are reported and we evaluate the method's efficiency to different shapes and number of objects. [Work supported by NIH and CenSSIS.]

2:00–2:15 Break

2:15

2pBBa5. Effect of intermittent applications of continuous ultrasound on the viability, proliferation, morphology and matrix production of chondrocytes in 3-D matrices.

Joseph A. Turner (Dept. of Eng. Mech., Univ. of Nebraska-Lincoln, Lincoln, NE 68588, jaturner@unl.edu), Sandra Noriega, Tarlan Mammedov, and Anu Subramanian (Univ. of Nebraska-Lincoln, Lincoln, NE 68588)

Chondrocytes, the cellular component of articular cartilage, have long been recognized as strain-sensitive cells, have the ability to sense mechanical stimulation through surface receptors and intracellular signaling pathways. This response has been exploited to facilitate chondrocyte culture in *in vitro* systems such as those that use hydrostatic pressure, dynamic compression, hydrodynamic shear, as well as low-intensity pulsed ultrasound (US). While the ability of US to influence chondrogenesis has been documented, the precise mechanisms of US induced stimulation are unclear. Thus, a critical need remains to evaluate the impact of US on chondrocytes in 3-D cultures, a necessary microenvironment for maintaining chondrocyte phenotype. Here, chondrocytes seeded in 3-D scaffolds were subjected to continuous ultrasound stimulation at several frequencies for the same number of cycles, applied twice in a 24-hour period. Non-US stimulated scaffolds served as the control. Both groups were maintained in culture for 10 days and were assayed at the conclusion of the culture period (total DNA content, morphology, and cartilage specific gene expression). Our results show that chondrocytes stimulated with continuous US for predetermined time intervals possessed 1.2 to 1.4-times higher cellular viability than the control as well as higher levels of type-II collagen and aggrecan mRNA expression.

2:30

2pBBa6. Lung hemorrhage at and near resonance: Pulse duration and pulse number.

Diane Dalecki, Sally Z. Child, and Carol H. Raeman (Dept. of Biomed. Eng., and the Rochester Ctr. for Biomed. Ultrasound, Univ. of Rochester, Rochester, NY 14627)

Research from our lab has shown that low-frequency (∼100–1000 Hz) underwater sound can produce mammalian lung hemorrhage. For adult mice, the pressure threshold for lung damage is ∼2 kPa for a 3-min continuous wave exposure at the lung resonance frequency (∼300 Hz). Sound-induced lung hemorrhage was studied for exposure below (200 Hz) and above (500 Hz) lung resonance. The threshold for lung damage is lowest for exposure at the lung resonance frequency. Furthermore, a series of experiments was performed to investigate effects of pulse duration and number of pulses on lung hemorrhage produced by exposure to underwater sound at lung resonance frequency. The resonance frequency of each mouse lung was determined using an acoustic scattering technique. In one set of experiments, the extent of lung hemorrhage was assessed for increasing pulse durations ranging from 1–180 s. In another set of experiments, extent of lung hemorrhage was assessed for increasing number of pulses. Extent of lung hemorrhage increased with increasing pulse duration and increasing number of pulses. The lung resonance frequency can shift higher or lower during sound exposure. The results of this work are relevant to establishing safety guidelines for swimmers and divers exposed to underwater sound fields.

2:45

2pBBa7. Effective medium model of human lung response to low-frequency sound.

Mark S. Wochner, Yurii A. Ilinskii, Mark F. Hamilton, and Evgenia A. Zabolotskaya (Appl. Res. Labs., Univ. of Texas, P.O. Box 8029, Austin, TX 78713-8029, mwochner@arlut.utexas.edu)

This presentation is an extension of work described previously [Ilinskii *et al.*, J. Acoust. Soc. Am. **120**, 3194 (2006)] on modeling the response of human lung to low-frequency underwater sound. A lumped element model with alveoli represented as truncated octahedra forming a periodic lattice with cubic symmetry was developed to capture the microscopic properties of collagen and elastin. The lattice is deformed quasistatically to determine the three elastic constants associated with the macroscopic behavior of the system. In reality lung tissue is likely isotropic and therefore a method of averaging is utilized to determine the two Lamé constants of the effective medium. The volume of the lung is varied to simulate tidal breathing. The Lamé constants are determined for the given lung volume and used in a commercial finite element package to calculate the amplitude of vibration due to low-frequency acoustic excitation. The resulting spectral response and scattered sound field are calculated for a water-loaded viscoelastic sphere composed of the effective lung medium. Increase in lung volume tends to decrease the resonance frequency, but increasing stiffness due to collagen tends to increase the resonance frequency. Competition of these effects is discussed. [Work supported by ONR and ARL IR&D.]

3:00

2pBBa8. Time reversal acoustic focusing with liquid-filled reverberator. Yegor Sinelniov, Andrey Vedernikov (ProRhythm Inc., 105 Comac St., Ronkonkoma, NY 11779), Alexander Sutin, and Armen Sarvazyan (Artann Labs., Inc., West Trenton, NJ 08618)

The use of solid acoustic reverberators for temporal and spatial focusing of acoustic energy based on time reversal acoustic (TRA) principle was described in the literature. We experimentally and theoretically demonstrated that the liquid-filled TRA reverberators can also efficiently focus acoustic energy and compared the advantages of solid and water-filled reververators. A theoretical model was developed to explore the factors defining the efficiency of TRA focusing, providing the design constraint for the water-filled reververators. The model allows evaluation of the spatial and temporal characteristics of TRA focused acoustic field formed as a result of numerous reflections of ultrasound within the reverberator. The TRA focused field structure, its dependence on the shape and size of the resonator, ultrasound frequency, and attenuation were investigated for the standard and binary modes of TRA focusing. The experiments with custom built liquid-filled acoustic resonators confirmed the predictions of a developed theory, including sharpening of the focal area and increasing of the focal intensity in a binary mode of TRA focusing. The conducted research supports suggestion that such liquid-filled reverberators can be considered as a base for a miniature limited range ablation devices for biomedical applications.

TUESDAY AFTERNOON, 5 JUNE 2007 SEMINAR THEATER, 3:30 TO 5:00 P.M.

Session 2pBBb

Biomedical Ultrasound/Bioresponse to Vibration: Imaging and Detection Theory

Bruno Durning, Chair
Tufts Univ., Dept. of ECE, Medford, MA 02155

Contributed Papers

3:30

2pBBb1. Fast computation of spatial transfer function for ultrasound imaging. Emre H. Guven (Dept. ECE, Northeastern Univ., Boston, MA 02115, eguven@ece.neu.edu), Eric Miller (Tufts Univ., Medford, MA 02155), and Robin Cleveland (Boston Univ., Boston, MA 02215)

A fast method for computing the spatial transfer function of ultrasound transducers is presented with application to rectangular transducers that are focused in one axis only. No closed form solutions exist for this application but several numerical techniques have been described in the ultrasound imaging literature. Our motivation is the rapid calculation of imaging kernels for physics based diagnostic imaging where current methods are computationally demanding. The spatial transfer function to be calculated is a spatial convolution of the transducer surface and the Green's function. A 3-D version of the overlap-save method, which is a method for digital filtering of long data sequences, has been employed to obtain a fast computational algorithm. Further efficiency is gained by using separable approximations of the 3-D convolution through the singular value decomposition. The tradeoff between accuracy and spatial sampling rate is explored to determine appropriate parameters for a specific transducer. Comparisons with standard tools such as Field II will be presented. [Work supported by NIH and CenSSIS.]

3:45

2pBBb2. The causal impulse response for circular pistons in viscous media. James F. Kelly and Robert J. McGough (Dept. of Elec. and Computer Eng., Michigan State Univ., East Lansing, MI 48824)

A causal impulse response for the Stokes wave equation is derived for calculations of transient pressure fields generated by circular pistons in viscous media. The causal Green's function is numerically verified using the material impulse response function approach. The causal, lossy impulse response for a baffled circular piston is then calculated within the near-field and the far-field regions using expressions previously derived for the fast near-field method. Expressions for apodized pistons evaluated in the far-field region are also demonstrated. Transient pressure fields in viscous media are computed with the causal, lossy impulse response and compared to results obtained with the lossless impulse response. The numerical error in the computed pressure field is quantitatively analyzed for a range of viscous relaxation times and piston radii. Results show that the largest errors are generated in locations near the piston face and for large relaxation times, and errors are relatively small otherwise. These results suggest that this causal impulse response is ideal for time-domain calculations that simultaneously account for diffraction and frequency-dependent attenuation in viscous media. [This work was partially supported by NIH Grant 1R01 CA093669.]

4:00

2pBBb3. Stress and strain relaxation mechanisms in soft tissue: An inverse problem and solution. Ricardo Leiderman (Program of Mech. Eng.—EE/COPPE, Federal Univ. of Rio de Janeiro, Rio de Janeiro, Brazil), Gearoid P. Berry, Jeffrey C. Bamber (Inst. of Cancer Res. and Royal Marsden Hospital NHS Trust, Sutton, UK), Assad A. Oberai (Rensselaer Polytechnic Inst., Troy, NY), and Paul E. Barbone (Boston Univ., Boston, MA)

Elastography refers to a collection of ultrasound imaging techniques that allow mechanical strain distributions to be imaged and noninvasively quantified *in vivo*. The time scales over which the tissue response is typically measured range from about a millisecond (the typical duration of a radiation force "push pulse") to about one second (the typical time scale of freehand quasistatic compression) used in strain imaging. Soft tissue is widely recognized as having both fluid and solid phases which can move independently of each other, giving rise to stress/strain relaxation effects. Furthermore, the fluid exists within several "compartments" of the soft tissue, notably, the vasculature (including both the hemal and lymphatic vessels) and the extravascular space (i.e., the interstitium). Of course, due to permeability of microvessel walls in both vascular networks, fluid is often exchanged between these compartments. Through mathematical models of tissue deformation, we explore the macroscopic effects of different microscopic relaxation mechanisms. We show that different microscopic relaxation mechanisms result in different spatio-temporal patterns of strain relaxation. We then focus on one such mechanism, and we formulate and solve an inverse problem that measures the microvessel density and permeability from the time-history of a measured strain distribution.

4:15

2pBBb4. Is the Kramers-Kronig causal relationship between ultrasonic attenuation and dispersion maintained when phase aberrations distort the field incident on a phase sensitive aperture? Adam Q. Bauer, Karen R. Marutyan, Mark R. Holland, and James G. Miller (Washington Univ. in St. Louis, One Brookings Dr., Campus Box 1105, St. Louis, MO 63130)

The objective of this investigation was to determine whether the causality-induced link between ultrasonic attenuation and dispersion remains valid when the measured signal loss arises as a consequence of phase cancellation at the face of a phase-sensitive receiver rather than from intrinsic losses within the medium under study. The frequency-dependent apparent attenuation and phase velocity were obtained from through-transmission measurements of two flat and parallel plastic polymer plates, Plexiglas^{TM} and Lexan^{TM}, exhibiting an approximately linear with frequency attenuation coefficient and logarithmic with frequency phase velocity. Phase distortion was achieved by machining a step into one side of each plastic plate. Through-transmission measurements were performed in a water tank using 5 MHz center frequency single element planar transmitting and receiving transducers. The causal (Kramers-Kronig) link between apparent phase velocity and the apparent attenuation coefficient in the presence of phase distortion was examined for both plastics over a bandwidth ranging from 3 to 7 MHz. Results demonstrate that the Kramers-Kronig link between the apparent attenuation coefficient and apparent phase velocity dispersion remains causally consistent even in the presence of aberrating media.

4:30

2pBBb5. Three dimensional ultrasound elasticity imaging. Michael S. Richards, Jonathan M. Rubin (Univ. of Michigan, University Hospital, Dept. of Radiology, Ann Arbor, MI 48109), Assad A. Oberai (Rensselaer Polytechnic Inst., Troy, NY), and Paul E. Barbone (Boston Univ., Boston, MA 02115)

The aim of our work is to develop and evaluate an ultrasound (US) technique to quantitatively measure and image the shear modulus of soft tissues in three dimensions (3D). It is widely recognized that breast tissue pathologies, such as neoplasia, often alter biomechanical properties. Thus, the intended application of our work is the detection and characterization of breast tissue lesions, via elastic modulus imaging, to improve the specificity of breast cancer screening. To that end, we have designed and characterized algorithms which 1) provide 3-D motion estimates from 3-D US images and 2) solve the 3-D inverse problem to recover shear elastic modulus. The size and contrast accuracy of the reconstructed modulus distributions in tissue mimicking phantoms are presented. Inclusions as small as 5mm, some with contrasts marginally above unity, were successfully and clearly reconstructed. The effect of the boundary conditions and regularization methods on the reconstructed modulus images and the uniqueness of the solution are also discussed. In addition, preliminary modulus reconstructions created from clinical 3-D US breast images acquired in a mammography mimicking system are presented.

4:45

2pBBb6. Application of the continuous wavelet transform to acoustic emissions generated by joint and muscle motion. Wayne Fischer and Joe Guarino (Dept. of Mech. Eng., Boise State Univ., 1910 University Dr., Boise, ID 83725, wfische@boisestate.edu)

The subject matter of this presentation will refer to the preliminary development of a non-destructive and non-invasive diagnostic method using low-frequency acoustic emissions to characterize and diagnose joint and muscle disorders. Low-frequency acoustic emissions have had limited effectiveness when used in the past to characterize and diagnose joint and muscle disorders because Fourier transform techniques were not capable of describing when a specific frequency occurred during an acoustic emission event. With the development of techniques that decompose a signal into time-frequency representations using wavelet analysis it is now possible to describe complex transient signals. While the continuous wavelet transform (CWT) method has already made an impact within many areas of the medical sciences such as EEG analysis, ECG analysis, and DNA-sequence analysis, the method is now becoming popular for analyzing muscle and joint acoustic emissions from the hip, knee, and elbow joints. This paper will present the results of our application of the CWT to the analysis of acoustic emissions from the shoulder joint.

TUESDAY AFTERNOON, 5 JUNE 2007 SALON B, 1:30 TO 4:15 P.M.

Session 2pEA

Engineering Acoustics, Underwater Acoustics and Signal Processing in Acoustics: Acoustic Technologies for Coastal Surveillance and Harbor Defense

Roger T. Richards, Chair
Naval Undersea Warfare Ctr., 1176 Howell St., Newport, RI 02841

Chair's Introduction—1:30

Invited Paper

1:35

2pEA1. Swimmer detection sonar network. Peter J. Stein, Amy Vandiver, (Sci. Solutions, Inc., 99 Perimeter Rd., Nashua, NH 03063, pstein@scisol.com), and Geoffrey S. Edelson (BAE Systems, Nashua, NH 03061)

The Swimmer Detection Sonar Network (SDSN) was designed to be a cost effective method to protect a large area from terrorist swimmers. The in-water system consists of a number of sonar nodes, each consisting of a set of air-backed parabolic dish transducers that are used to both transmit and receive in sets of independent narrow beams. Each dish/channel can transmit and process its own unique signal. The Sonar Network is therefore composed of a distributed group of nodes each providing a set of independent narrow-beam sonars. This allows for strong rejection of interfering clutter, resulting in excellent performance. The nodes/channels are also synchronized, allowing for multi-static signal processing. A suite of signal processing algorithms has been developed for automated detection, tracking, and classification, including a fine-bearing estimation that achieves approximately 1 deg accuracy. These algorithms will be discussed. Data will be shown that shows the performance against swimmers and the possibilities for bi-static detection and classification. The SDSN has been productized and is now available for wide-scale deployment. It is a cost effective means for large harbor facilities to reliably detect underwater threats at long ranges.

Contributed Papers

2:00

2pEA2. Clearance of harbor navigation channels with high-resolution bottom surveys at 10 knots. James Glynn, Jr, Christian de Moustier, and Lloyd Huff (Ctr. for Coastal and Ocean Mapping, UNH, 24 Colovos Rd., Durham, NH 03824)

The safety of navigation channels leading to or within a harbor can be ensured by repeat high-resolution bottom surveys to detect new hazards or obstacles. This task requires a sonar system capable of acquiring high-resolution acoustic backscatter imagery and bathymetry. Because of the generally shallow water depths (20 m), survey efficiency dictates data collection over wide swaths at high speeds. We have demonstrated these capabilities in October 2006 in New York harbor, NY, with a Klein 5410 multibeam side-looking sonar system yiedling swath coverage of at least 7 times the water depth at a nominal survey speed of 10 knots. This has been achieved by integrating the hull-mounted sonar system with precision attitude (0.01 deg) and timing (10-6 s) references, and by designing and implementing a full vector processing algorithm to obtain co-registered high-resolution bathymetry and acoustic backscatter imagery, allowing us to resolve sub-meter targets. [Work funded by NOAA-NMFS].

2:15

2pEA3. Detection and target echo enhancement in shallow water using the Decomposition of the Time Reversal Operator. Claire Prada, Julien de Rosny, Dominique Clorennec, Jean-Gabriel Minonzio, Alexandre Aubry, Mathias Fink (Lab. Ondes et Acoustique, ESPCI, Paris, France), Lothar Bernière, Sidonie Hibral, Philippe Billand, and Thomas Folégot[a] (Altran Technologies, Technopôle Brest Iroise, Brest, France)

A rigid 24-element source-receiver array (SRA) in the 10 to 15 kHz frequency band, connected to a programmable electronic system was deployed in the bay of Brest (France) during spring 2005. In this 10 to 18 m deep environment, backscattered data from submerged targets were recorded. Successful detection and focusing experiments in very shallow water using the Decomposition of the Time Reversal Operator (DORT method) are shown. The ability of the DORT method to separate the echo of a target from reverberation is demonstrated. For a target close to the bottom at 350 m range, active focusing using the first invariant of the time reversal operator was achieved, showing a target echo enhancement. Furthermore, the localization of the target in the water column is obtained using RAM [Collins *et al.*, J. Acoust. Soc. Am. **89** 3 (1991)]. [Work supported by the French DGA/SPN under contract number 02 77 154 00 470 75 53.] [a] now affiliated to NATO Undersea Research Centre, La Spezia, Italy

2:30

2pEA4. Estimation of passive acoustic threat detection distances in estuarine environments. Brian Borowski, Heui-Seol Roh, Barry Bunin, and Alexander Sutin (Stevens Inst. of Technol., 711 Hudson St., Hoboken, NJ 07030)

The Maritime Secure Laboratory (MSL) at Stevens Institute of Technology supports research in a range of areas relevant to harbor security, including passive acoustic detection of underwater threats. The difficulties in using passive detection in an urban estuarine environment include intensive and highly irregular ambient noise and the complexity of sound propagation in shallow water. MSL measured the main parameters defining the detection distance of a threat: source level of a scuba diver, transmission loss of acoustic signals, and ambient noise. The source level of the diver was measured by comparing the divers sound with a reference signal from a calibrated emitter placed on his path. Transmission loss was measured using the transmission of a sweep signal (1–100 kHz) from the calibrated emitter. The passive sonar equation was then applied to estimate the range of detection. Estimations were done for various recorded noise levels, demonstrating how fluctuations in noise level and the mobility of the diver influence the effective range of detection. Finally, analytic estimates of how a hydrophone array improves upon the detection distance calculated by a single hydrophone are shown. [This work was supported by ONR project No. N00014-05-1-0632: Navy Force Protection Technology Assessment Project.]

2:45

2pEA5. Acoustic noise produced by ship traffic in the Hudson River estuary. Heui-Seol Roh, Barry Bunin, George Kamberov, and Alexander Sutin (Stevens Inst. of Technol., 711 Hudson St., Hoboken, NJ 07030)

This paper presents results of measurements of acoustic noise in Hudson River Estuary near Manhattan in the frequency band 10–100 kHz. The Estuary has very complex sound propagation conditions due to the extremely shallow and high time- and space variability of the water characteristics. The acoustic noise was recorded by a set of hydrophones and the acoustic measurements were accompanied by ship traffic video recording using the video-based Surface Traffic Surveillance system. This video system allowed us to map various boats and ships and to find distances between them and the hydrophone system. The measurements provided acoustic noise data for different kinds of ships in Hudson River, their dependencies on frequencies, and distances. The measurements of noise for various distances were applied for estimation of sound attenuation in a wide frequency band. We calculated the sound attenuation coefficient showing the attenuation loss of an acoustic signal in addition to cylindrically spreading loss. The recorded levels of acoustic noise and estimation of transmission loss were used for estimations of detection distances of underwater threats that are presented in our other paper. [This work was supported by ONR Project No. N00014-05-1-0632: Navy Force Protection Technology Assessment Project.]

3:00–3:15 Break

3:15

2pEA6. Performance of a high-frequency acoustic forward-scatter barrier in a dynamic coastal environment. Karim G. Sabra, Stephane Conti, Philippe Roux, W. A. Kuperman (Marine Physical Lab., Scripps Inst. of Oceanogr., UC San Diego, San Diego, CA 92093-0238, ksabra@mpl.ucsd.edu), J. Mark Stevenson, Alessandra Tesei, Piero Guerrini, Piero Bonni (NATO Undersea Res. Ctr., La Spezia, Italy), and Tuncay Akal (UC San Diego, San Diego, CA 92093-0238)

This paper investigates the performance of a high-frequency ''barrier'' or ''tripwire'' surveillance system based on forward scattering for shallow water (<20 m depth) choke points, such as harbor entrance. Harbor entrances are usually regions of very high ambient noise and often are reverberation-limited environments, making them challenging for some traditional ASW techniques, i.e., techniques inherited from blue-water ASW. Detecting a target by measuring its forward-scattered field is of interest because sound scattered in the forward direction is generally higher than in the backward direction. We will present a series of proof-of-concept experiments to test the feasibility of an acoustic tripwire based on forward scattering using two vertical source and receive arrays operated over a 135-m range at a center frequency of 15 kHz with about 8 kHz of bandwidth. The signal of interest was the aberration (in space and time) caused by the acoustic forward scattering field of a crossing object (scuba tank, 2-m-long steel cylinder and 1-m-diam steel sphere). Autonomous signal processing techniques based on the spatio-temporal coherence of

the signals measured across the vertical receive array were applied to enhance the signal of interest, yielding a usable detection threshold of several dB.

3:30

2pEA7. Improved range and characterization of harbor security systems through bistatic detection. Marcia Isakson, Colin Bown, Karl Rehn, and Nathan Crowe (Appl. Res. Labs., Univ. of Texas, P.O. Box 8029, Austin, TX 78713-8029)

There are three critical design drivers for harbor security systems: cost per unit area of coverage, coverage of geometrically denied areas such as very shallow waters and under and around piers, and probability of false alarm. Bistatic detection can address all three of these issues. First, many harbor security systems operate with overlapping coverage. These adjacent systems offer an existing source of bistatic signals. By analyzing the signal from these adjacent sources, the coverage for each sound head is increased with no increase in system cost. Second, the strategic placement of additional sources will allow coverage in denied areas for little additional cost. Lastly, additional detection will lower false alarm rates. In this study, measurements from an overlapping harbor security system will be analyzed to determine the effect of additional bistatic analysis on detection thresholds and coverage range.

3:45

2pEA8. Application of maximum length sequences to photoacoustic chemical analysis. Ralph T. Muehleisen and Arash Soleimani (Civil and Architectural Eng., Illinois Inst. of Technol., Chicago, IL 60616, muehleisen@iit.edu)

There is a great need for inexpensive, rugged, portable, and versatile chemical detectors for use in both security and environmental measurement. Current sensors that meet the inexpensive, portable, and rugged criterion are usually limited in sensitivity and dedicated to detecting a limited number of chemicals. Sensors designed for airborne measurement typically cannot be used to measure surface chemicals. The photoacoustic method is one of the most sensitive techniques for trace analysis in both the air and on surfaces. Unfortunately, photoacoustic systems are typically expensive, usually not portable, and usually cannot be used for both airborne and surface chemical analysis. A new design for a photoacoustic measurement system is proposed that utilizes maximum length sequences (MLS) to modulate multiple, inexpensive, fixed frequency, laser diodes. The MLS modulation and post-acquisition correlation processing should provide a very high signal-to-noise measurement without need for lock-in amplifiers, high power pulsed lasers, optical modulators, or resonant measurement cells. These changes should allow for the design of a rugged, portable, inexpensive photoacoustic measurement system that can be used for both airborne and surface trace chemical detection.

4:00

2pEA9. Acoustic emission mechanism from scuba diving equipment. Dimitri M. Donskoy (Davidson Lab., Stevens Inst. of Technol., 711 Hudson St., Hoboken, NJ 07030)

The energy-based analysis of the underwater acoustic emission mechanism from scuba diving equipment shows that the primary originating source of acoustic emission is turbulent air flow pressure fluctuations during the inhale phase of breathing. A scuba air tank contains a substantial amount of energy in the form of compressed air. This energy is gradually released as the air is consumed during breathing. As air expands from high pressure in the tank to lower pressure supplied to the second stage regulator, it rushes through the first stage regulator's valve and channels creating highly turbulent air flow. The turbulent pressure fluctuations excite structural vibrations of the valve housing and connected air tank and piping in a very broad frequency range spreading above 100 kHz. In turn, vibration causes sound emission into surrounding medium (water). [Work supported by ONR].

TUESDAY AFTERNOON, 5 JUNE 2007 ALPINE WEST, 1:30 TO 3:45 P.M.

Session 2pMUa

Musical Acoustics: Voice Production and Pedagogy

Ingo R. Titze, Chair
Univ. of Iowa, Speech Pathology and Audiology, Iowa City, IA 52242-1012

Chair's Introduction—1:30

Invited Papers

1:35

2pMUa1. Singers' self-perception of harmonics. Lisa Popeil (Voiceworks, 14431 Ventura Blvd. #402, Sherman Oaks, CA 91423)

Historically, singers have relied on the sensation of resonance as a guide in vocal production. The use of terms such as focus and placement have been primary tools in traditional vocal pedagogy. In a newer method of acoustic training, singers can be taught to discern three bands of harmonics which are key elements of vocal timbre: ring, brightness, and nasality. Each of these harmonic bands has particular sonic and expressive characteristics and are easily amplified or attenuated. Ring, at 2500–3500 Hz, is the most penetrating of the three and is acutely heard by the human ear. Ring aids singers in being heard without electronic amplication. Brightness, comprised of harmonics in the approximate range of 5–15 kHz, lacks the penetrating quality of ring but is an important conveyor of the emotion of happiness and expressive traits such as sincerity and innocence. Nasality, broadly occuring in the 200–2000 Hz range, has a characteristic buzziness and is used in commercial singing styles for amplitude and expressive enhancement. Live vocal demonstrations will show how a singer can create, isolate, and combine ring, brightness, and nasality.

1:55

2pMUa2. Acoustically-guided vocal tract modifications for singing. Brad Story (Univ. of Arizona, P.O. Box 210071, Dept. of Speech, Lang., and Hearing Sci., Tucson, AZ 85721)

The sound quality of a specific vowel can be dramatically altered by subtle modifications of the vocal tract shape. These modifications create changes in the pattern of formant frequencies. For example, the well-known singing formant, which is a clustering of resonance frequencies, is typically the result of constricting the epilaryngeal space or expanding the lower pharyngeal space to create a large cross-sectional area discontinuity between them. Other modifications such as lip protrusion/spreading or larynx lowering/raising will also impose changes on the formant frequency pattern that may be desirable for singing or speech production. This presentation will focus on the acoustic sensitivity of the resonance frequencies to subtle perturbations of specific vowel configurations. Using calculated sensitivity functions, it will be shown how specific regions along the vocal tract can be constricted or expanded to perturb one or more of the formant frequencies. In effect, this technique provides a means of ''tuning'' the vocal tract shape to produce a desired frequency response. [Work supported by NIH R01-DC04789.]

2:15

2pMUa3. The 1:6 ratio in vocal pedagogy. Brian B. Monson (Dept. of Speech, Lang., and Hearing Sci., Univ. of Arizona, P.O. Box 210071, Tucson, AZ 85721)

The so-called singer's formant or singer's formant cluster is created in the vocal tract by a narrow epilaryngeal tube opening, such that the ratio of the cross-sectional area of the pharynx is approximately six times greater than that of the epilarynx outlet. This appears to be accomplished by maintaining a comfortably low laryngeal position while manipulating other structures of the vocal tract. Experimental research was conducted to examine the potential of pedagogical implementation of this principle. Experimentation consisted of training graduate voice student subjects at Brigham Young University to use the one-to-six ratio to achieve the singer's formant. Using the acoustical output from the singers for analysis, predictions of actual vocal tract shapes before and after vocal tract manipulation will be shown. The results of this study may offer valuable information regarding the training of voice students to access the singer's formant.

2:35

2pMUa4. Semi-occluded vocal tract postures and their application in the singing voice studio. John P. Nix (Music Dept., The Univ. of Texas at San Antonio, San Antonio, TX 78249) and C. Blake Simpson (Univ. of Texas Health Sci. Ctr. at San Antonio, San Antonio, TX 78249)

Many singing teachers employ semi-occluded vocal tract postures in their teaching. These postures can be divided into three types: (1) postures where the semi-occlusion remains consistent over time, as in singing vowels into a straw, the sustained phonation of voiced fricative consonants and the sustained phonation of nasal consonants; (2) postures where the occlusion is oscillatory, as in the lip buzz, the raspberry, and the rolled /r/; (3) postures where the semi-occlusion or occlusion is very transitory, as is found in the semi-vowels /j/ and /w/ and the voiced plosive consonants. The presentation will review the benefits of these semi-occluded postures, show videoendoscopic images of the pharynx and larynx and electroglottography of the vocal folds while the semi-occluded postures listed above are used as pilots to the vowels /i/, /u/, and /a/, and will demonstrate some of the traditional uses of the semi-occluded postures in singing pedagogy.

2:55

2pMUa5. Source-vocal tract interaction in singing. Ingo R. Titze (Dept. of Speech Pathol. & Audiol., Univ. of Iowa, Hawkins Dr., Iowa City, IA 52242)

It has been known for centuries that certain vowels are easier to sing on certain pitches. Much of traditional and modern singing pedagogy is focused on this vowel F0 interaction. Unlike most musical instruments, where the resonator is specifically designed to resonate many of the source frequencies at every note played, the vocal instrument relies on the use of inertive reactance (away from resonance) to boost various clusters of harmonics. Acoustic reactance is positive (inertive) below a vocal tract resonance (a formant), zero at resonance, and negative (compliant) above resonance. The skill in selecting a vowel for a given F0 is to place as many of the key harmonics (2F0, 3F0, and 4F0) on the inertive portions of the reactance curves. The process is aided by shrinking the epilarynx tube, which biases the reactance curves toward positive values over the entire F0 range. [Work supported by NIDCD.]

Contributed Papers

3:15

2pMUa6. A real-time display system for singing voice development.
David M. Howard, Helena Daffern, Jude Brereton (Audio Lab., Intelligent Systems Res. Group, Dept. of Electron., Univ. of York, Helsington, York, YO10 5DD, UK), Graham F Welch, Evangelos Himonides (Univ. of London, London, WC1H 0AL UK), and Andrew W. Howard (SARAND Ltd., Cambridge, UK)

Central to any pedagogical nurturing of singing development is the provision of some form of meaningful feedback to the developing singer. Singing teachers draw on their personal experiences within an essentially oral culture where expertise is handed down from teacher to student generation by generation. The teacher is engaged in a psychological translation of the student's performance, and a dual possibility thereby exists for the misinterpretation of information; the teacher may not describe the student's performance appropriately and/or the student may not understand how to modify his or her singing behavior as intended. The provision of quantitative visual feedback provides a physical basis for vocal development. This paper will describe a real-time display system for singing training known as "WinSingad," which enables acoustic and voice source aspects to be viewed in real-time on a PC. The system has been used in singing lessons and has been universally welcomed by students and teachers alike for its ease of use and display clarity. Specific aspects of voice development are now linked with particular displays and these will be explored in this presentation.

3:30

2pMUa7. A non spectrum-based visual display tool.
Peter R. Nordquist, R. Dean Ayers, Daisuke Kato, and Lewis Nakao (Southern Oregon Univ., 1250 Siskiyou Blvd., Ashland, OR, 97520)

A software program was developed to help musicians learn to tune just intonation intervals. A reference tone is played and Lissajous-like figures present a visual representation of the interval the musician's sound makes with the reference tone. This approach is interesting, because the musician receives coordinated aural and visual feedback in real time, and this visual representation is produced without the overhead of doing a Fourier transform. Experiments that modify the figures to produce a usable representation of timbral differences, also using a non spectrum-based algorithm, are planned. [Work supported by the Veneklasen Foundation.]

TUESDAY AFTERNOON, 5 JUNE 2007 — ALPINE WEST, 4:15 TO 5:30 P.M.

Session 2pMUb

Musical Acoustics: Mini-Concert of Yodeling as a Style of Vocal Production

William J. Strong, Chair
Brigham Young Univ., Dept. of Physics and Astronomy, Provo, UT 84602

Chair's Introduction—4:15

Kerry Christensen—yodeler—became interested in alpine yodeling while spending two years in Austria. He used his yodeling skills at Walt Disney's Epcot Center for almost eight years and will visit over 20 states and two or three countries this year. Kerry specializes in all styles of yodeling. He will perform alpine, classical, humorous, and other yodeling styles during this mini-concert.

TUESDAY AFTERNOON, 5 JUNE 2007 — CANYON ROOM A, 1:30 TO 3:30 P.M.

Session 2pNS

Noise: Workshop on Standardization for Soundscape Techniques II

Brigitte Schulte-Fortkamp, Cochair
Technical University Berlin, Inst. of Fluid Mechanics and Engineering Acoustics, Einsteinufer 25, D-10587 Berlin, Germany

Bennett M. Brooks, Cochair
Brooks Acoustics Corporation, 27 Hartford Turnpike, Vernon, CT 06066

1:30

Working Groups, Part 3

The combination of physical acoustical measurements with scientific evaluation of perceptual responses to environmental sound, known as soundscaping, is an essential method for the assessment and actualization of positive outdoor environments. Working groups will be organized around the following areas of interest, as expressed by persons responding to the workshop announcement or at meeting registration. Working groups will develop presentations on problems, solutions, and recommended actions. To further develop and refine the methods of soundscaping the following are needed: (1) Catalog of correlations between physical parameters and perceptual responses. (2) Standardization of a terminology lexicon of soundscape descriptors. (3) Standardization of measurement procedures. (4) Recommendations for perceptual evaluation and analysis. Working group discussions from the morning will continue, focusing on (1) what has been done in the past, (2) what should be done now, and (3) how may this be accomplished?

2:30

Final Group Presentation

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

TUESDAY AFTERNOON, 5 JUNE 2007 GRAND BALLROOM A, 1:00 TO 5:00 P.M.

Session 2pPA

Physical Acoustics: Ultrasound in Condensed Matter, Neutrons, Nano-Materials, Magnetism

Albert Migliori, Cochair
Los Alamos National Lab., Los Alamos, NM 87545

Veerle M. Keppens, Cochair
Univ. of Tennessee, Materials Science and Engineering, Dougherty Hall, Knoxville, TN 37996

Chair's Introduction—1:00

Invited Papers

1:05

2pPA1. Bulk versus nanoscale WS_2: Finite size effects and solid state lubrication. J. L. Musfeldt, S. Brown (Dept. of Chemistry, Univ. of Tennessee, Knoxville, TN 37996, musfeldt@utk.edu), I. Mihut, J. B. Betts, A. Migliori (Los Alamos Natl. Lab. Los Alamos, NM), A. Zak, and R. Tenne (Weizmann Inst. of Sci., Israel)

Metal dichalcogenide nanostructures have recently attracted attention due to their unique closed-cage structures, hierarchy of length scales, and outstanding solid state lubrication behavior. To understand the finite size effects and tribological properties in these nanoscale materials, we measured the low temperature specific heat of layered and nanoparticle WS_2. Below 9 K, the specific heat of the nanoparticles deviates from that of the bulk. Further, the thermal response of the nested nanoparticles deviates from the usual T ^{3} dependence below 4 K because of both finite size effects and inter-particle-motion entropy. This separation of nanoscale effects from T^3 dependence can be modeled by assuming that the phonon density of states is flexible, changing with size and shape of the nanoparticle. We also invoke relationships between the low temperature T^3 phonon term, Young's modulus, and friction coefficient to assess the difference in the tribological properties. Based on this analysis, we conclude that the improved lubrication properties of the nanoparticles are extrinsic in origin.

1:30

2pPA2. Elastic constants, Blackman diagrams, and new lanthanide−actinide insights. Hassel Ledbetter (Mech. Eng. Dept., Univ. of Colorado, Boulder, Colorado 80309, Hassel.Ledbetter@colorado.edu)

Using monocrystal elastic constants and Blackman diagrams, one can infer material interconnections, physical-property trends, and knowledge about interatomic bonding. After reviewing briefly the f.c.c.-metal case, focus shifts to Ce, Pu, Th, with known monocrystal f.c.c. elastic constants, the Cij. For U and a few other lanthanide-actinide cases, one can deduce the f.c.c. Cij. From these results, for the lanthanides-actinides, there follow several conclusions: (1) elastic anisotropy ranges widely; (2) Poisson ratios are low; (3) interatomic bonding varies widely; (4) against other f.c.c. metals, all show unusual negative Cauchy pressures (three-body forces); (5) a strong covalent-bonding component occurs, perhaps related to localized (or semilocalized) f-electrons; (6) delta-Pu behaves most oddly; (7) delta-Pu may share some bonding features with f.c.c. alkali metals. [Work supported by DoE, NSF, State of Florida.]

1:55

2pPA3. Magnetoacoustic studies as a probe of electron systems. Alexey Suslov (NHMFL, 1800 E. Paul Dirac Dr., Tallahassee, FL 32310, souslov@magnet.fsu.edu)

The pulse-echo technique was used to probe the electron systems in solids. The measurements were performed in the frequency range 10–500 MHz, at temperatures down to 0.3 K and in the magnetic fields up to 18 T. (a) Acoustic quantum oscillations were investigated in URu_2Si_2, $AuZn$, and Sr_2RuO_4. Extracted parameters of the electron systems are in good agreement with data known from other experiments and theoretical calculations. Hydrostatic pressure effect on superconductive transition in Sr_2RuO_4 was studied. It is found that the sound speed increases, critical temperature and critical fields decreases, and transition becomes broader

under the pressure. Magnetic field dependencies of ultrasound attenuation are compared with theoretical predictions. (b) Surface acoustic waves were used for contactless measurements of conductivity in low dimensional structures. The value of complex ac conductivity was extracted from simultaneous measurements of the sound attenuation and velocity. Such measurements allowed to study, for example, mechanisms of conductivity in a dense array of SiGe quantum dots and localization of the 2D carries in GaAs/AlGaAs and Si/SiGe heterostructures in the extreme quantum limit. NHMFL is supported by the NSF Cooperative Agreement No. DMR-0084173 and the State of Florida. The ultrasonic research at the NHMFL is supported by the In-House Research Program.

2:20

2pPA4. Scattering methods applied to lattice dynamics in thermoelectric materials. Raphaël P. Hermann (Institut fur Festkörperforschung, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany)

Inelastic neutron scattering and x-ray scattering or nuclear resonance scattering are powerful techniques that yield insight into the microscopic origin of macroscopic material behavior. Progress in nuclear resonance scattering that allows element specific studies of lattice dynamics and, in particular, element specific measurements of the phonon density of states, atomic displacement parameters, and force constants, will be discussed. Recent results from lattice dynamics studies of thermoelectric materials, such as filled skutterudites, clathrates, and Zn_4Sb_3, will be presented in conjunction with results from macroscopic determinations of the thermodynamical properties of these materials, such as heat capacity or elastic constants obtained by ultrasound spectroscopy. [The European Synchrotron Radiation Facility is acknowledged for provision of the synchrotron radiation facility at beamlines ID18 and ID22N. Part of this research was carried out at the FRJ-II research reactor in Jülich, Germany.]

2:45

2pPA5. The charge ordering transition as probed by ultrasound. David Mandrus, Manuel Angst (Mater. Sci. and Technol. Div., Oak Ridge Natl. Lab., P.O. Box 2008, MS6056, Oak Ridge, TN 37831), Yanbing Luan, and Veerle Keppens (The Univ. of Tennessee, Knoxville, TN 37996)

Charge ordering (CO) phenomena are found in many correlated electron systems but in general are poorly understood. A classical example of CO is found in magnetite, Fe_3O_4, which undergoes a CO transition (the so-called Verwey transition) at 120 K. Magnetite is a poor model system for studying CO; however, despite nearly 70 years of study, there is still no generally accepted description of the transition. In recent years several new materials that display CO transitions have been discovered, including Fe_2OBO_3 and $LuFe_2O_4$. These new materials are proving to be far better model systems for studying CO than magnetite. In this talk the Landau theory of CO transitions will be reviewed, and the behavior of the elastic response of $LuFe_2O_4$ will be discussed in this context. [Work at ORNL supported by DOE BES Division of Materials Science and Engineering. Work at UT supported by NSF DMR-0506292.]

3:10–3:25 Break

3:25

2pPA6. Elasticity in metallic glasses. Takeshi Egami, Valentin Levashov (Dept. of Mater. Sci. and Eng. and Dept. of Phys., Univ. of Tennessee, Knoxville, TN 37996-1508), Rachel Aga, and Jamie Morris, J (Oak Ridge Natl. Lab., Oak Ridge, TN 37831)

The unique nature of elasticity in metallic glasses will be discussed with particular focus on the intrinsic anelasticity. Although the bulk modulus of a metallic glass is comparable in magnitude to that of the corresponding crystalline solid, the shear modulus is always lower by 20% to 30%. This is because shear deformation of a metallic glass produces not only the geometrical deformation but also local topological changes of atomic bonding. Even in the glassy state there is some local residue of liquidity due to local structural frustrations, and this makes the shear deformation in metallic glasses intrinsically anelastic. On this point glasses are fundamentally different from crystals. This intrinsic anelasticity results in anomalous dependence of shear modulus and anelastic loss on frequency and temperature, including the low-temperature two-level state behavior. Based upon computer simulation, neutron scattering experiment, and theory, the intrinsic nature of anelasticity will be shown to be a part of the big picture of the structure and dynamics of metallic glasses.

3:50

2pPA7. Pulse-echo ultrasound in pulsed magnetic fields. D. Rickel (Los Alamos Natl. Lab. and Natl. High Magnetic Field Lab., MS E536, Los Alamos, NM 87545, drickel@lanl.gov)

As the technology of high-speed data acquisition evolves along with the ability to record multi-megabyte continuous streams of data, the application of pulse-echo ultrasound to transient measurements have become possible. I will discuss a system that has been developed at the National High Magnetic Field Laboratory for measurements of sound speed and attenuation in materials subjected to intense pulsed magnetic fields. The magnetic field pulses have millisecond durations and can only be repeated a few times a day. We are able to process from a single magnetic pulse, a record of sound speed that reveals structural changes as a function of magnetic field. We are not alone in this effort; at least two other groups at other high magnetic field laboratories are using similar techniques [C. Proust *et al.*, Lab. National des Champs Magnetiques Pulses, Toulouse France, UMR 5147CNRS-INSA-UPS; Wolf *et al.*, "New Experimental Techniques for Pulsed Magnetic Fields-ESR and Ultrasonics," Physica B **294–295**, 612–17 (2001)]. This presentation is intended to acquaint the audience with the techniques of setting up a pulse-echo ultrasound system by taking advantage of modern digitizing systems available and computer based post processing using commercially available application software. I will present data from experiments that we have carried out and discuss the precision with which the sound speeds can be determined.

4:15

2pPA8. Thermal diffusivity of $Bi_2Sr_2CaCu_2O_8$ superconductor measured using open-cell photoacoustic technique: Effect of nano-Ag addition. Hasan A. Alwi, Mary A. B. Narreto, Kong Wei, and Roslan Abd-Shukor (School of Appl. Phys., Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia)

Thermal diffusivities of $Bi_2Sr_2CaCu_2O_8$ superconductor at room temperature with the addition of different amounts of nano Ag ($Bi_2Sr_2CaCu_2O_8$-Ag_x with $x=0$-1.0) were measured using the open-cell photoacoustic technique. The thermal diffusivity was obtained by analyzing the phase of photoacoustic signal of thermally thick samples instead of analyzing the amplitude signal of thermally thick-to-thin samples. Two methods of phase analysis of thermally thick samples were applied, that is, Calderon's method and the thermal diffusion model. The phase analysis is suitable where the dominanant mechanism contributing to the photoacoustic signal is thermal diffusion alone, which is true for $Bi_2Sr_2CaCu_2O_8$ superconductor. We have found that the thermal diffusivity increases with the amounts of nano-Ag. The values of thermal diffusivity obtained were between 0.012 50-0.001 28 and 0.016 06-0.002 30 cm^2/s for Ag_0 to $Ag_{1.0}$.

4:30

2pPA9. Determination of third-order elastic constants of langasite single crystals through force-frequency effect. Haifeng Zhang, Joseph A. Turner, Jiashi Yang (Dept. of Eng. Mech., Univ. of Nebraska-Lincoln, Lincoln, NE 68588-0526, hfzhang@bigred.unl.edu), and John A. Kosinski (U.S. Army RDECOM CERDEC, Fort Monmouth, NJ 07703-5211)

Langasite resonators are of recent interest for a variety of applications because of their good temperature behavior, good piezoelectric coupling, low acoustic loss, and high Q factor. Third-order elastic constants are responsible for many nonlinear effects associated with langasite resonators including the force-frequency effect. This effect describes the shift in resonant frequency a resonator experiences due to the application of a mechanical load. The determination of the third-order elastic constants through the force-frequency effect relies on an accurate theoretical understanding of this effect. In this article, expressions for the frequency shift of langasite resonators subjected to a pair of diametric forces are obtained using the perturbation integral in conjunction with the finite element method. Experimental measurements of the force-frequency effect for various langasite resonator samples with plano-plano configuration are also discussed. The third-order elastic constants of langasite single crystals are extracted based on the measured data in conjunction with the derived expressions. The results are compared with previous measurements of third-order elastic constants for langasite obtained using transit-time methods. [Work supported by ARO.]

4:45

2pPA10. Diffuse waves in solids: Can you hear the texture of a crystal? Andrew Norris (Mech. and Aerosp. Eng., Rutgers Univ., Piscataway, NJ 08854)

Diffuse waves are a steady state reverberation that partitions energy equally among modes of a system. In an isotropic solid of infinite extent the equipartition defines a well known equation for the spectral density d, which is proportional to the square of the frequency. The proportionality factor depends on the material properties through an average of the inverse third power of the wave speeds. This talk describes the analogous equation for diffuse wave density in a crystal. The first result is that the density d is a matrix or tensor quantity, which possesses the material symmetry of the solid. The properties of the matrix are discussed both for the forward problem of determining d for a given anisotropic material, and the inverse question of what information can be derived from d about the local material texture. The general form of the spectral density presented is related to the admittance matrix for a point force, as will be explained.

TUESDAY AFTERNOON, 5 JUNE 2007 — GRAND BALLROOM B, 1:30 TO 4:30 P.M.

Session 2pPP

Psychological and Physiological Acoustics: Pitch, Binaural and Spatial Hearing Suppression (Poster Session)

Christopher A. Brown, Chair
Arizona State Univ., Speech and Hearing Science, Box 870102, Tempe, AZ 85287-0102

Contributed Papers

All posters will be on display from 1:30 p.m. to 4:30 p.m. To allow contributors an opportunity to see other posters, contributors of odd-numbered papers will be at their posters from 1:30 p.m. to 3:00 p.m. and contributors of even-numbered papers will be at their posters from 3:00 p.m. to 4:30 p.m.

2pPP1. Dominance region for pitch at low fundamental frequencies: Implications for pitch theories. Brian Moore, Brian Glasberg, Idriss Aberkane, Samantha Pinker (Dept. of Exp. Psych., Univ. of Cambridge, Downing St., Cambridge CB2 3EB, UK), and Candida Caldicot-Bull (Univ. of Cambridge, Cambridge CB3 9DP, UK)

The dominant region for pitch was measured for complex tones with low fundamental frequency (F0=35 and 50 Hz). The tones contained 59 harmonics, added in cosine or random phase. The harmonics were split into two groups; group A containing harmonics 1-K and group B containing harmonics (K+1)-N. On each trial, two successive complex tones were presented. In one, the harmonics in group A were shifted down by deltaF0 and the harmonics in group B were shifted up by deltaF0. In the other tone, the shifts were in the opposite direction. The tones were presented in random order and the subject had to indicate which had the higher pitch. The pitch judgements followed the components in group B for small K and the components in group A for large K. The frequency corresponding to the middle of the transition region was taken as the center of the dominant region, fdom. The value of fdom varied markedly

across subjects but typically corresponded to harmonic numbers above the 6th, for both phase conditions. Thus, the dominant harmonics were unresolved. These results indicate that resolution of individual harmonics is not the key factor determining the location of the dominant region. [Work supported by the MRC.]

2pPP2. Why pitch strength decreases with increasing harmonic number in complex tones. D. Timothy Ives and Roy D. Patterson (CNBH, Dept. Physiol., Development, and Neurosci., Univ. of Cambridge, Cambridge, UK)

A melodic pitch experiment was performed to demonstrate the importance of temporal resolution for pitch salience. The experiments show that notes with a low fundamental (75 Hz) and relatively few resolved harmonics support better performance than comparable notes with a higher fundamental (300 Hz) and more resolved harmonics. Two four-note melodies were presented to listeners and one note in the second melody was changed by one or two semitones. Listeners were required to identify the note that changed. There were four orthogonal stimulus dimensions: F0 (75 and 300 Hz), lowest frequency component (3, 7, 11, or 15), number of harmonics (2, 4, or 8), and degree of component rove (1 or 3). Performance decreased as the frequency of the lowest component increased for both F0s, but performance was better for the lower F0. The spectral and temporal information in the stimuli were compared using the Auditory-Image Model [Bleeck *et al.*, Acta Acust. **90**, 781–788 (2004)]. Peaks in the time-interval profile of the auditory image can explain the decrease in performance as F0, and spectral resolution increase. Spectral profiles of the same auditory images do not contain sufficient resolution to explain the performance. [Work supported by U.K. MRC (G0500221, G9900369).]

2pPP3. The effect of phase, fundamental, and lowest component on the perception of octave height. Ralph van Dinther and Roy D. Patterson (CNBH, Dept. Physiol., Development and Neurosci., Univ. of Cambridge, Downing St., Cambridge, CB2 3EG, UK)

Attenuation of the odd harmonics of a complex harmonic tone increases the perceived octave height and eventually leads to a shift of one complete octave in the perception. In a 2AFC experiment, we assessed how much the odd harmonics had to be attenuated to make a sound indistinguishable from its octave, first when the components were in cosine phase and then when the phase of the odd harmonics was shifted by $\frac{1}{3}\pi$ or $\frac{1}{2}\pi$. Thresholds were measured for four fundamental frequencies (31, 63, 125, 250 Hz) and four lowest harmonic numbers (2, 4, 8, 16). The results show that when the odd harmonics are phase shifted, the attenuation required to make the test sound indistinguishable from its octave decreases dramatically, from between 20 and 30 dB to less than 5 dB. A model based on the time-interval profile of the auditory image [Patterson, J. Acoust. Soc. Am. **98**, 1890–1894 (1995)] was used to explain the data; 95% of the predicted thresholds fall within one standard deviation of the empirical data. The spectral profile did not have sufficient resolution to predict the data and it could not explain the effect of the phase manipulation. [Work supported by the U.K. Medical Research Council (G0500221, G9900369).]

2pPP4. Temporal relationship between speech auditory brainstem responses and phonemes envelopes. Idrick Akhoun, Stephane Gallego, Evelyne Veuillet, and Lionel Collet (Laboratoire Neurosci. et Systemes Sensoriels, 50, avenue T. Garnier, F-69007 Lyon, France, idrick.akhoun@chu-lyon.fr)

Auditory brainstem responses evoked by synthetic phonemes (speech-ABR) were recorded on normal hearing subjects stimulated monaurally on the right ear at 60 dB sensation level. The speech-ABR consists of an onset response (OR) followed by the frequency following response (FFR), which results of the summation of phase locking underlying activities in the auditory cells of the brainstem nuclei. The FFR mimicked accurately the envelope of the stimulus, defined as the absolute value of the stimulus filtered at the cutoff frequency of the speech ABR spectrum. However, the FFR was more shifted relative to the vowel than the OR did relative to the onset of the stimulus, which is close to the cochlear delay usually reported. Little interindividual discrepancies were found. Delay values give information about the sites of generation of the speech-ABR. This method may help to objectivate the temporal encoding of phonemes in the brainstem. Hence the potential assessing of speech intelligibility, as temporal speech envelopes retain perfect intelligibility [R. Drullman, J. Acoust. Soc. Am. **98**, 1796–1798 (1995)]. [Work supported by CNRS.]

2pPP5. Experiments on perceiving the missing fundamental by using two harmonic components tone. Yutaka Iitomi and Takahide Matsuoka (Utsunomiya Univ., Yoto 7-1-2, Utsunomiya, Tochigi, Japan 321-8585, mt063203@cc.utsunomiya-u.ac.jp)

There are some methods on acoustic experiments for perceiving the missing fundamental. Listening to one of two harmonic components from each ear and listening to a complex tone of two harmonic components from each ear are the two examples. The latter method may perceive the combination tones also. Computational experiments of the above-mentioned two methods were done by using AIM (Auditory Image Model). The effect of the value of the fundamental and the effect of the number of harmonic components on extraction of the missing fundamental information and the information of combination tones were investigated. Finally, the result of the latter method was compared with the result of the former method and the effect of combination tones on extraction of the missing fundamental information was investigated. As a result of investigating many data, the fundamental could be perceived easier in the latter method (tone containing the combination tones) than in the former method. Its mechanism was considered.

2pPP6. Phase effects in F0 discrimination and temporal fine structure. Andrew J. Oxenham and Christophe Micheyl (Dept. of Psych., Univ. of Minnesota, N640b Elliott Hall, 75 East River Rd., Minneapolis, MN 55455-0344)

Pitch discrimination with only high-order (unresolved) harmonics is dependent on their relative phases and is thought to be based on the temporal envelope of the waveform after peripheral filtering. In contrast, when low-order harmonics are present, phase effects disappear, and pitch may be derived from the estimated frequencies of the individual resolved harmonics. The dichotomy between the envelope-based periodicity from unresolved harmonics and the temporal fine-structure (or spectrally) based estimates of individual frequencies from resolved harmonics forms the basis of the well-known two-mechanism theory of pitch. Recently, the early idea that listeners use temporal fine-structure cues in unresolved harmonics to estimate the overall F0 has been revived as a third intermediate mechanism to account for why accurate F0 discrimination, normally associated with resolved harmonics, can sometimes be achieved in conditions that produce phase effects. Here we show that it is not necessary to resort to a third mechanism. Instead, we show that the relative component phases affect the instantaneous frequency distributions in ways that could influence the coding of frequencies for individual, partially resolved, harmonics. Implications for the interpretation of temporal fine structure in pitch and other auditory functions, such as speech perception, are discussed. [Work supported by NIH R01DC05216.]

2pPP7. Neural correlates of auditory streaming with unresolved harmonics. Ifat Yasin (Dept. of Exp. Psych., South Parks Rd., Univ. of Oxford, Oxford OX1 3UD, UK) and Christopher Plack (Lancaster Univ., Lancaster LA1 4YF, UK)

The magnetoencephalographic negative wave N1m may be used as an indicator of auditory stream segregation [Gutschalk *et al.*, J. Neurosci. **25**, 5382–5388 (2005)]. When a repeating sequence of a pure-tone triplet (ABA-) is perceived as a single stream, the N1m amplitude is relatively

small and consistent with the inter-stimulus-interval (ISI) between successive tones. When the sequence is perceived as segregated, the N1m amplitude is relatively large and consistent with the longer ISI between tones of each segregated stream. The present study used the electroencephalographic equivalent, wave N1, to investigate stream segregation based solely on temporal cues. Each triplet was comprised of complex tones with an $f0=62.5$, with unresolved harmonics summed either in sine phase, or in alternating sine-cosine phase, with a pitch corresponding to f0 and 2* f0, respectively. The effect of disrupting segregation was investigated by introducing increasing amounts of temporal jitter imposed by reducing the ISI for a complex within a triplet. Initial analyses tend to suggest that N1 amplitude is increased if the conditions for segregation are appropriate (when presentation rate is increased). Furthermore, N1 amplitude decreases as the amount of jitter increases, consistent with a disruption of segregation. [Work supported by ESRC and MRC.]

2pPP8. The effect of fundamental frequency in simulated electric-acoustic hearing. Christopher A. Brown and Sid P. Bacon (Dept. of Speech and Hearing Sci., Arizona State Univ., P.O. Box 870102, Tempe, AZ 85287-0102)

Individuals with residual hearing restricted to low frequencies are candidates for electric-acoustic stimulation (EAS). When low-frequency acoustic information is added to either real or simulated high-frequency electric stimulation, speech recognition often improves dramatically. This may reflect the availability of fundamental frequency (f0) information in the acoustic region. We tested this directly. In particular, we examined the relative contributions of f0 and the amplitude envelope of speech by replacing the low-frequency speech with a tone that was modulated either in frequency to track the f0 of the speech, in amplitude with the extracted envelope of the low-frequency speech, or both. A female talker was combined with various backgrounds and processed with a four-channel vocoder to simulate electric hearing. Across all backgrounds, intelligibility improved significantly when a tone tracking f0 was added to vocoder stimulation and further still when both f0 and amplitude envelope cues were applied. These results confirm the importance of f0 information (at least under simulated EAS) and indicate that significant information can be provided by a tone that tracks f0 or f0 and amplitude envelope cues. [Work supported in part by NIH.]

2pPP9. The effect of interaural differences of time on speech intelligibility in simulated electric-acoustic hearing. Christopher A. Brown and Sid P. Bacon (Dept. of Speech and Hearing Sci., Arizona State Univ., P.O. Box 870102, Tempe, AZ 85287-0102)

Individuals with residual hearing restricted to frequencies below about 500–750 Hz have recently been implanted with a relatively short electrode array designed to preserve as much of the residual hearing as possible. Those who also have some low-frequency hearing in the non-implanted ear have the potential to benefit from interaural time differences (ITD). The goal of the current experiments was to determine whether such benefit exists in simulations of implant listening and how it is influenced by sensation level (SL) in the low frequencies. Presentation was via headphones. Target and distractor speech were low-pass filtered at 500 Hz. The target was presented diotically and the distractor was presented with a 0-s (spatially centered image) or 600-s (image to the right) ITD. The target and distractor were also processed by a four-channel vocoder and presented to the left ear only. The SL of the low-frequency speech was varied both symmetrically and asymmetrically. In the symmetric conditions (15–60 dB SL), intelligibility improved by as much as 40% when the target and distractor were spatially separated. In the asymmetric conditions (60 dB in one ear, 20–50 dB in the other), approximately 15%–20% improvement was observed in all conditions. [Work supported by NIH and NOHR.]

2pPP10. Laboratory rats do not use binaural time cues to localize sound. Christina M. Wesolek,[a] , Gimseong Koay, and Henry E. Heffner (Dept. of Psych. MS 948, Univ. of Toledo, 2801 W. Bancroft St., Toledo, OH 43606, Henry.Heffner@utoledo.edu)

The use of binaural time and intensity cues to localize sound can be investigated by determining the ability of a subject to localize pure tones in a free-field. Specifically, the ability to localize low-frequency tones, which do not produce an intensity difference at the two ears, demonstrates the use of the binaural phase (time) cue whereas the ability to localize high-frequency tones, to which the auditory system cannot phase lock, demonstrates the use of the binaural intensity-difference cue. Because previous studies of the laboratory rat (*Rattus norvegicus*) disagreed on the highest frequency that could be localized using binaural phase difference, the ability of rats to localize pure tones was reexamined. The results indicated that, contrary to previous studies, laboratory rats are not able to localize low-frequency tones even when they are amplitude modulated. Thus, it appears that laboratory rats are unable to use the binaural time-difference cue to localize sound. Because the previous studies were conducted before the widespread availability of spectrum analyzers, it is possible that their results were due to the presence of high-frequency harmonics in their low-frequency tones. These results have relevance for the anatomical and physiological study of binaural processing in laboratory rats. [a] Presently at Disney's Animal Kingdom, Lake Buena Vista, FL.

2p TUE. PM

2pPP11. Auditory evoked potential hearing measures of a group of bottlenosed dolphins (*Tursiops truncatus*). Kristen A. Taylor, Paul E. Nachtigall (Marine Mammal Res. Program, Hawaii Inst. of Marine Biol., Univ. of Hawaii, P.O. Box 1106, Kailua, Hawaii 96734), Mats Amundin, Pernilla Mosesson, Sunna Edberg, and Stina Karlsson (Kolmrdens Djurpark AB, SE-61892, Kolmrden, Sweden)

The hearing of the bottlenosed dolphins at Kolmrdens Djurpark, Sweden, was examined using a portable auditory evoked potential (AEP) system in order to examine the hearing capabilities of dolphins housed in quiet environments with an emphasis on age-related hearing variation. Audiograms were measured on two dolphins and modulation rate transfer functions (MRTF) were also measured on two animals. A complete audiogram (4–200 kHz) was obtained for the oldest dolphin, a 34 year old female named Vicky. Her audiogram showed no evidence of high-frequency hearing loss. Notwithstanding this finding, her click evoked auditory brainstem response (ABR) revealed a marked increase in interpeak latency that could be indicative of an underlying hearing defect. The audiogram obtained from for the male dolphin, a 24 year old named Pichi (measured from 4–107 kHz), demonstrated profound hearing loss at all frequencies. The measured MRTF results indicated typical odontocete following responses to rates exceeding 1000 Hz.

2pPP12. Hearing screening in bottlenose dolphins using single and multiple auditory evoked potentials. James J. Finneran (U.S. Navy Marine Mammal Program, Space and Naval Warfare Systems Ctr., Code 2351, 49620 Beluga Rd., San Diego, CA 92152), Dorian S. Houser (Biomimetica, Santee, CA 92071), Dave Blasko, Christie Hicks, Jim Hudson, Mike Osborn (The Mirage Dolphin Habitat, Las Vegas, NV 89109), and Kevin M. Walsh (Gulf World Marine Park, Panama City Beach, FL 32413)

Auditory thresholds were estimated in four bottlenose dolphins (*Tursiops truncatus*) by measuring auditory evoked responses to single and multiple sinusoidal amplitude modulated tones. Subjects consisted of two males and two females with ages from 4 to 22 years. Testing was conducted in air using a jawphone transducer to couple sound into the subjects lower right jaw. Carrier frequencies ranged from 10 to 160 kHz in one-half octave steps. Amplitude-modulated stimuli were presented individually and as the sum of four, five, and nine tones with unique carrier and modulation frequencies. Evoked potentials were noninvasively recorded using surface electrodes embedded in silicon suction cups. The presence or absence of an evoked response at each modulation frequency was assessed

by calculating the magnitude-squared coherence from the frequency spectra of the recorded epochs. All subjects exhibited traditional U-shaped audiograms with upper cutoff frequencies above 113 kHz. The time required for threshold estimates ranged from 30–45 min for single stimuli and 4–8 min for nine simultaneous stimuli. Agreement between thresholds estimated from single stimuli and multiple, simultaneous stimuli was generally good, suggesting that multiple stimuli may be used for quick hearing assessment when time is limited. [Work supported by ONR.]

2pPP13. Effects of ear coverage and reflected sound on the localization of sound. Angelique Scharine, Tim Mermagen, Justin MacDonald, and Mary Binseel (Army Res. Lab., Human Res. and Eng. Directorate AMSRD-ARL-HR-SD; APG, MD 21005-5425)

Previous research has shown that listeners wearing helmets with greater ear coverage perform worse on localization tasks. However, the helmets studied were selected from those commonly in use and differed in suspension systems and profiles. Three versions of the same helmet design, differing only in the ear coverage (0%, 50%, 100%), were compared in this study. Sounds were presented from 12 azimuthal locations spaced 30 deg apart in the presence of a white noise masker. Twelve listeners completed a localization task while wearing each of the helmets as well as with no helmet in two different acoustic environments. As ear coverage increased, localization performance decreased. The effects of early reflections, though small, were consistent across the different coverage conditions. The effect of ear coverage and its interaction with the acoustic environment will be discussed in terms of its significance for real-world environments. In addition, head-related transfer-functions (HRTFs) were measured for each listener in each of the head conditions. A model of localization performance based on changes to the HRTF will be described and applied to the collected data.

2pPP14. Multiple echoes precedence effect. Gongqiang Yu and Ruth Y. Litovsky (Waisman Ctr., Univ. of Wisconsin—Madison, Madison, WI 53705)

The precedence effect has been explored extensively using a lead and a single lag (simulated echo). For click stimuli, when the lead-lag delay is a few ms, discrimination of directional changes in the lag are poorer than for the lead. This study was aimed at determining whether the effects would be upheld in a three-source paradigm and to explore the extent to which the three sources interact. Three binaural click pairs (Lead, Lag1, and Lag2) were presented over headphones. Discrimination of directional changes in each click pair was measured using an ABX, 2AFC task, for delays of 0–130 ms. Results replicated classic findings with a single lag, but also showed that (1) for delays above 16 ms a temporal order effect resulted in poorer lead discrimination and better Lag2 discrimination; (2) echo thresholds were complicated by the addition of Lag2; and (3) an interaction was observed between Lag1 and Lag2 at very brief time delays such that summing localization resulted in improved discrimination of lagging sound sources. These results suggest that in a multi-echo situation the directional cues from echoes that occur after the classic lead-lag pair can contribute in the localization process and introduce complexities.

2pPP15. Spatial generalization in short-term perceptual adaptation to novel auditory spaces. I-Fan Lin, Timothy Streeter, Barbara Shinn-Cunningham (Auditory Neurosci. Lab., Dept. of Cognit. and Neural Systems, Boston Univ., 677 Beacon St., Boston, MA 02215, ifan1976@cns.bu.edu), Nat Durlach, and Lorraine Delhorne (Boston Univ., Boston, MA 02215)

Previous work shows that humans can rapidly adapt to novel mappings between auditory spatial cues and exocentric location and localize accurately with the novel mapping. Here, experiments using (1) a rotation and (2) a linear magnification of auditory space examined generalization of spatial adaptation to untrained or neglected regions of space. Individual head-related transfer functions (HRTFs) were used to simulate different source locations using headphones. Each experimental session was broken into three blocks: initial normal cues (measuring baseline performance), altered cues (showing adaptation), and final normal cues (measuring an adaptation aftereffect). In the altered cues trials, a source at X degrees was simulated using HRTFs that normally correspond to a source at (1) X +30 deg (rotation) or (2) 2X deg (linear magnification). After obtaining subjects' localization responses to the sound stimulus, feedback was given using a light-emitting diode located at the correct position (X deg). Results of these experiments show the extent to which training subjects to adjust their localization responses in one region of space affects how they localize sources in adjacent regions, and provide a measure of the spatial kernel that drives spatial auditory adaptation.

2pPP16. Interactive acoustical intimacy exploration. Bobby Gibbs II, Jonas Braasch, and Ted Krueger (Rensselaer Polytechnic Inst., 110 8th St., Troy, NY 12180)

A novel methodology to explore salient cues for acoustical intimacy is presented. Subjects are instructed to modify a set of sliders in a virtual acoustical environment to correlate with three intimacy settings: low, medium, and high. As the experiment proceeds, subjects are allowed to audition their choices and make modifications to achieve what they feel to be optimal settings. At the conclusion of the interactive phase, subjects are instructed to rank the (as yet unknown to them) parameters in terms of their overall effect on intimacy. Unknown to the subjects, each slider correlates to an acoustical parameter: direct-to-reverberant energy ratio, high-frequency attenuation, room size, and volume. Results from the experiment are discussed relative to concert-hall acoustics and virtual spaces.

2pPP17. Visual and auditory hemispheric cuing in horizontal sound localization. Norbert Kopčo (Dept. of Cognit. and Neural Systems, Boston Univ.; Percept. and Cognition Lab, Tech. Univ. of Košice, Slovakia, kopco@bu.edu), Beáta Tomoriová, and Rudolf Andoga (Tech. Univ. of Košice, Slovakia)

Experiments were performed to determine 1) whether *a priori* information influences sound localization, and 2) whether the influence depends on the modality through which the information is provided. Localization performance was measured for transient auditory stimuli originating in the frontal horizontal plane. In most runs, a cue preceded the stimulus and indicated (correctly or incorrectly) the hemisphere (left vs. right) from which the subsequent target arrived. The cues differed by modality and the cue-to-target onset asynchrony (SOA: 400 to 1600 ms). The listeners were instructed to focus their attention to the cued side. A follow-up experiment evaluated the effect of eye fixation on the visual-cue performance. Results show modality-dependent effects of cuing in terms of both bias and standard deviation in responses. A cue that indicated an incorrect side biased the responses towards its side in both modalities, while a visual correct-side cue caused either no bias or a lateral bias. A visual cue that indicated an incorrect side also caused an increase in the standard deviations at the largest SOA, suggesting that the mechanisms that control auditory spatial attention are modality dependent and that they operate on the time scale of seconds. [Work supported by the Slovak Science Grant Agency.]

2pPP18. Characteristics of visually-induced auditory spatial adaptation. I-Fan Lin (Dept. of Cognit. and Neural Sys., Boston Univ., 677 Beacon St., Boston, MA 02215), Norbert Kopčo (Boston Univ., Boston, MA 02215), Jennifer M. Groh (Duke Univ., Durham, NC), and Barbara G. Shinn-Cunningham (Boston Univ., Boston, MA 02215)

In humans, visual and auditory spatial information arise in different reference frames, with auditory information being head-centered based on interaural cues, whereas visual information derives from the retinal activation, an eye-centered signal. This study investigated whether visually-guided recalibration of auditory space occurs in a head-centered, eye-centered or a hybrid (combination of both) reference frame. Subjects made saccades to combined auditory-visual targets. The visual component of the target was displaced laterally by 5°. Interleaved auditory-only trials served to evaluate the effect of the mismatched visual stimulus on auditory space. To dissociate head- from eye-centered reference frames, the initial fixation position of the eyes was varied. The results reflected contributions of both coordinate frames. First, the magnitude of the induced shift was affected by the eye-centered location of the targets, but occurred at a consistent location in head-centered space. Second, when subjects were trained using one fixation position and tested using a different fixation position, the magnitude of the induced shift was reduced, but the target locations that showed the greatest shift did not move. The hybrid nature of these effects is reminiscent of recent demonstrations of eye position modulation in the auditory pathway of non-human primates. [Work supported by NIH]

2pPP19. The role of suppression in temporal masking effects. Lata A. Krishnan and Elizabeth A. Strickland (Dept. of Speech, Lang. and Hearing Sci., Purdue Univ., 1353 Heavilon Hall, 500 Oval Dr. West, Lafayette, IN 47907)

The temporal effect refers to the change in signal-to-masker ratio at threshold for a short-duration tone as it is delayed from the onset of a longer-duration masker. Evidence suggests that this phenomenon is related to changes in gain in the cochlea due to acoustic stimulation by the masker. Research has suggested that for off-frequency maskers, the temporal effect is consistent with a decrease in suppression, which may depend on a decrease in gain at the suppressor frequency. Most previous studies have utilized simultaneous masking paradigms to measure the temporal effect. The present study used tonal maskers in a forward masking paradigm, and measured temporal masking curves to elucidate the role of suppression in temporal masking effects. A previous study had also showed that the pattern of the temporal effect with level depended not only on the degree of hearing loss at the signal frequency, but also on the degree of hearing loss above the signal frequency. The present study examined this further by using listeners with normal hearing as well as listeners with a notched cochlear hearing loss. Results will be analyzed in terms of changes in gain at signal and suppressor frequencies. [Work supported by Lions Club McKinney Outreach Award.]

TUESDAY AFTERNOON, 5 JUNE 2007 — TOPAZ ROOM, 1:30 TO 5:15 P.M.

Session 2pSA

Structural Acoustics and Vibration: Launch Vehicle and Space Vehicle Acoustical and Vibration Environments and General Topics in Structural Acoustics and Vibration

James E. Phillips, Chair
Wilson, Ihrig and Associates, Inc., 5776 Broadway, Oakland, CA 94618-1531

Chair's Introduction—1:30

Invited Papers

1:35

2pSA1. Derivation of aeroacoustic environments for the crew exploration vehicle. Michael Yang (ATA Eng., Inc., 11995 El Camino Real, Ste. 200, San Diego, CA 92130)

The Crew Exploration Vehicle (CEV) is designed to provide safer, more reliable space transportation capability in the quest for human space exploration. This article covers the development of an external aeronoise model which was fit to generic and Saturn/Apollo configuration wind tunnel data, and anchored to Atlas and Titan flight data. The predictions for a combined aerodynamic/propulsion system load case while firing the Launch Abort System (LAS) engines during flight is also presented, along with SEA methods for predicting internal responses.

1:55

2pSA2. Prediction of liftoff acoustic environments for launch pads with covered ducts. Michael Yang (ATA Eng., Inc., 11995 El Camino Real, Ste. 200, San Diego, CA 92130)

The acoustic environment experienced by a launch vehicle is typically most severe during the liftoff phase. The launch pad can be designed with a deflector to redirect the exhaust plume into a covered duct. This is done to reduce the fluctuating pressure field experienced by the vehicle. The Eldred method is frequently used to predict liftoff environments, but does not specify how to model the effects of the covered duct. Techniques used to model the covered duct are reviewed and compared in this paper.

2:15

2pSA3. High-frequency radiation from edges and drive points on vibrating panels. Donald Bliss and Linda Franzoni (Dept. of Mech. Eng., Duke Univ., Durham, NC 27708)

High-frequency radiation from subsonic waves on vibrating panels is shown to have directivity characteristics that can be expressed analytically by a limited set of parameters. Far-field mean-square pressures are independent of the panel length, indicating the radiation is associated with the edges and drive points. A Fourier transform approach to surface velocity shows that it can be reinterpreted in physical space in terms of singularity functions at the edges, namely the delta function and its derivatives. This interpretation leads to monopole, dipole, quadrupole, etc., edge radiators with relative strengths that depend on surface-wave Mach number. The radiation cannot be explained simply in terms of uncancelled volumetric sources at edges and drive points; this often-stated idea is not correct except under very restricted circumstances. A correct physical interpretation of the radiation is provided both in physical space and transform space. Basic directivity patterns are identified, associated with right and left traveling waves and the correlation between them at edges and drive points. The role of boundary conditions at the panel edge is illustrated, as are the effects of forcing. The analytical characterization of the radiation is shown to be particularly straightforward in the high-frequency broadband limit.

2:30

2pSA4. Control of aircraft interior noise using heterogeneous (HG) blankets. Kamal Idrisi, Marty Johnson, and James Carneal (Vib. and Acoust. Labs., Virginia Tech., 136 Durham Hall, Blacksburg, VA 24061, idrisi@vt.edu)

This study is concerned with the passive control of vibration and sound radiation of interior cabin noise in aircraft at low frequencies (<500 Hz) using heterogeneous (HG) blankets. HG blankets consist of poroelastic media with small embedded masses, which act similar to a distributed mass-spring-damper system. HG blankets have shown significant potential to reduce low-frequency radiated sound from structures, where traditional poroelastic materials have little effect. A mathematical model of a double panel system with an acoustic cavity and HG blanket was developed using mobility and impedance matrix methods. Theoretical predictions are validated with experimental measurements. Results indicate that proper tuning of the HG blankets can achieve in broadband reductions in sound transmission through the double panel system with less than 10% added mass. Future work includes expanding the model and experiment to multiple panel systems.

2:45

2pSA5. Steady-state vibration absorption using undamped linear substructures. Ilker Murat Koc (Dept. of Mech. Eng., Istanbul Tech. Univ., Inonu Cad. No. 87 Gumussuyu, Istanbul, Turkey 34437, ilker.koc@itu.edu.tr), Adnan Akay (Carnegie Mellon Univ., Pittsburgh, PA 15213), and Antonio Carcaterra (Univ. of Rome, 00184, Rome, Italy)

This study extends the previous applications of linear energy sinks to steady-state vibration absorption. First developed for the absorption of transient vibrations, linear energy sinks also act as effective vibration absorbers under steady-state excitation. However, their effectiveness depends on the value of excitation frequency with respect to the natural frequency of the primary structure around which the frequencies of the attached oscillators of energy sink are distributed. Vibratory energy is absorbed efficiently for excitation frequencies above the natural frequency of the primary structure, while absorption is not as effective at lower excitation frequencies. [Research carried out while AA served at NSF.]

3:00

2pSA6. Diffraction of acoustic waves and embedding theory. Richard V. Craster, Elizabeth A. Skelton (Dept. of Mathematics, Imperial College, London, UK), and Andrey V. Shanin (Moscow State Univ., Russia)

The diffraction and scattering of sound waves by sharp edges and corners is a ubiquitous feature of acoustic interactions with structures. This talk is on a technique called embedding which is a relatively new, and under used, idea in diffraction theory. The fundamental idea of embedding is that one only ever solves a single master, canonical, scattering problem (or set of problems). Thereafter, to extract the far-field behavior for any plane wave incidence on the same geometry, one only manipulates results from this master problem. The result is that quantities (directivities) previously dependent upon two parameters (incident and observed angle) become factorized into products of a function of a single variable, together with a simple trigonometric term; this facilitates rapid numerical evaluation. In principle, this should revolutionize many scattering calculations in every area where diffraction occurs as one need only evaluate the directivities from the set of canonical problems once. Given these directivities one manipulates them to generate solutions for more general problems, rather than continually recalculating and re-evaluating. At present, the theory has some limitations and the talk will cover these and describe how they can be overcome.

3:15–3:30 Break

3:30

2pSA7. The energy flow for guided waves at and inside the surface of an ensonified fluid loaded elastic cylindrical shell via the Poynting vector field: Preliminary results. Cleon E. Dean (Phys. Dept., P.O. Box 8031, Georgia Southern Univ., Statesboro, GA 30460-8031, cdean@GeorgiaSouthern.edu) and James P. Braselton (Georgia Southern Univ., Statesboro, GA 30460-8093)

The Poynting vector field is used to show preliminary results for the energy flow both at the surface and inside an ensonified fluid loaded elastic cylindrical shell for both forward and retrograde propagating waves. The present work uses a method adapted from a simpler technique due to Kaduchak and Marston [G. Kaduchak and P. L. Marston, "Traveling-wave decomposition of surface displacements associated with scattering by a cylindrical shell: Numerical evaluation displaying guided forward and backward wave properties," J. Acoust. Soc. Am. **98**, 3501–3507 (1995)] to isolate unidirectional energy flows.

3:45

2pSA8. Low-wave-number turbulent boundary layer wall pressure measurements from vibration data on a cylinder in pipe flow. William K. Bonness and Dean E. Capone (Appl. Res. Lab., The Penn State Univ., State College, PA 16804)

Low-order vibration modes of a cylinder subjected to a fully developed turbulent boundary layer (TBL) in a pipe are measured and used to determine the low-wave-number content of energy in the boundary layer. The experiment is conducted using a 6-in.-diameter, thin-walled, aluminum test section filled with water flowing at 20 ft/s. Coupling of certain cylinder modes in the axial and radial directions allows use of the inverse method to determine the wave-number levels of TBL wall normal pressure and wall shear stress in the flow direction. These measurements are used to evaluate commonly used empirical models of the TBL wave-number pressure spectrum attributed to Corcos (1963) and Chase (1987) at lower wave numbers than have previously been reported. Preliminary results from several higher order cylinder modes confirm prior experimental findings that the Corcos model overestimates the low-wave-number pressures for these conditions by nearly 20 dB. The Chase model provides estimates within 3 dB of the measured low-wave-number pressure spectrum. [Work supported by Navsea 073R.]

4:00

2pSA9. Rayleigh waves guided by topography. Samuel D. M. Adams, Richard V. Craster, and Duncan P. Williams (Dept. of Mathematics, Imperial College London, South Kensington Campus, London, SW7 2AZ UK)

It would not be far-fetched to say that the work of Lord Rayleigh on surface guided waves has had fundamental and far-reaching effects upon modern life and many things we take for granted today, stretching from mobile phones through to the study of earthquakes. Many of these things take advantage of surface waves that are topographically guided thereby allowing energy to be carried in specific directions along some topography of the surface. Much of the emphasis has so far been placed on devices which are essentially thin rectangular ridge-like defects upon the surface. Indeed, experiments with these so-called SAW devices have demonstrated the presence of trapped waves. It remains to provide any convincing theory that captures this trapping effect for surface waves—this is our aim. We seek to resolve the issue of whether topography can support a trapped wave, whose energy is localized to within some vicinity of the topography, and to explain physically how trapping occurs. The trapping is first addressed by developing an asymptotic scheme that exploits a small parameter associated with the surface topography. We then provide numerical evidence to support results obtained from the asymptotic scheme; however, no rigorous proof of existence is presented.

4:15

2pSA10. Limiting performance and optimal synthesis of elastic-inertial multi-degree-of-freedom vibration isolation systems. Vyacheslav Ryaboy (Newport Corp., 1791 Deere Ave., Irvine, CA 92606)

This paper is concerned with optimal problems that seek to find the best vibration isolation performance achievable by a linear mechanical system with arbitrary structure and number of degrees-of-freedom. The solution is presented in form of inequality relating isolation efficiency, frequency domain, total mass, and overall static or quasi-static stiffness. The inequality is valid for all mechanical systems of the class, however complicated these systems may be. Partial optimal problems, such as mass minimization of a system with prescribed transmissibility function, are solved as intermediate steps in deducing the limiting performance inequalities. Synthesis of a vibration isolation system with prescribed properties is a closely related problem. It has multiple solutions that are presented in a systematized way; the class of the simplest systems allowing for a unique solution is defined.

4:30

2pSA11. A comparison between one-sided and two-sided Arnoldi-based model order reduction (MORe) techniques for fully coupled structural-acoustic analysis. R. Srinivasan Puri, Denise Morrey (School of Technol., Oxford Brookes Univ., Wheatley, Oxford, OX33 1HX, UK), and Jeffrey L. Cipolla (ABAQUS Inc., Providence, RI 02909-2499)

Reduced order models are developed for fully coupled structural-acoustic unsymmetric matrix models, resulting from Cragg's displacement/pressure formulation, using Krylov subspace techniques. The reduced order model is obtained by applying a *Galerkin* and *Petrov-Galerkin* projection of the coupled system matrices, from a higher dimensional subspace to a lower dimensional subspace, while matching the moments of the coupled higher dimensional system. Two such techniques, based on the Arnoldi algorithm, focusing on one-sided and two-sided moment matching, are presented. To validate the numerical techniques, an ABAQUS coupled structural-acoustic Benchmark problem is chosen and solved using the direct approach. First, the physical problem is modeled using ANSYS FE package and compared with closed form solutions. Next, ANSYS results are compared with nodal velocities obtained by generating reduced order models via moment matching. The results show that the reduced order models give a very significant reduction in computational time, while preserving the desired accuracy of the solution. It is also shown that the accuracy of the one-sided method could be further improved by using two-sided methods, where the Arnoldi vectors are *optimized* for chosen outputs. The accuracy of the approaches, convergence models, and computational times are compared.

4:45

2pSA12. Unsteady pressures on a ship hull. Michael Goody, Theodore Farabee, and Yu-Tai Lee (Naval Surface Warfare Ctr., Carderock Div., West Bethesda, MD 20817-5700)

Unsteady surface pressure measurements at locations distributed on the surface of a ship model hull and flow visualization of the bow wave and free surface are discussed. The pressure measurement locations are distributed over the hull surface from 15% to 70% of the model length. There are several additional pressure measurement locations on the hull surface adjacent to the bow wave. The measurements were performed in the David Taylor Model Basin using a ship model that is approximately 40 ft long and representative of a naval combatant at Froude numbers from 0.14 to 0.44. The measured surface pressure spectra are compared to predictions done using a RANS-statistical method and predictions done using an empirical formulation that is based on historical, flat-plate, surface pressure spectra. Scaling of the surface pressure spectrum and limited spatial coherence measurements are discussed. [Work sponsored by Office of Naval Research, Code 334.]

5:00

2pSA13. Generation and the measures of impact sound by stick-slip phenomenon at beam joint in buildings (the first report). Yasuaki Hayashi (Tasca Techno Corp., 2-10-4 Furou-Cho, Naka-Ku, Yokohama, 231-0032 Japan) and Hidemaro Shimoda (Koto-Ku, Tokyo, 135-8530 Japan)

It is often happened to be annoyed by the sound of an uncertain cause in the completed buildings. The phenomenon might be repeated indefinitely though most of these sounds are canceled with the passage of time. This paper reports a series of processes from the investigation of the cause, to effective measures on the case in a high rise housing complex. And the ascertained cause is thought to give a systematic explanation to this kind of uncertain sound in buildings. The outline of this paper is as follows. (1) It paid attention to the vibration wave form (phase) to which it propagated in the building frame to specify the position in the plane of the slab, the vibration accelerometers were arranged in two dimensional distribution on the slab, and the source was ascertained adequately. (2) It was clearly specified that the cause of generation was ''stick-slip phenomenon'' in the beam joint part from the wave form of the generated sound and its spectrum of the vibration. (3) Appropriate measures construction of completely controlling movement in this case was executed by being able to specify the cause of generation and the effect was confirmed.

Session 2pSC

Speech Communication: Frontiers of Spectrum Analysis with Speech Applications

Sean A. Fulop, Chair
California State Univ., Fresno, Dept. of Linguistics, 5245 N. Backer Ave., Fresno, CA 93740-8001

Chair's Introduction—1:30

Invited Papers

1:35

2pSC1. Complex peak time-frequency representations. Douglas Nelson (Dept. of Defense, Fort Meade, MD 20705)

Complex representations encode twice as much information as representations encoding energy alone. Complex surfaces may be manipulated by conventional complex arithmetic operations to extract information about individual signal components. Presented are two representations. The first is an energy distribution representing energy and instantaneous frequency as the surface magnitude and phase, and the second is a signal distribution in which the instantaneous value of the signal at each time is distributed linearly in frequency. In each representation, the surface is first processed to concentrate the surface along curves representing the instantaneous frequencies of individual signal components, the surface at each time is then reduced to a short vector representing only the complex surface peaks with the largest magnitude. For the energy distribution model, the peak representation may be used to detect, track, and process individual signal components. For the signal distribution model, it is demonstrated that noise and interfering signals may be removed and an estimate of the clean signal may be recovered by a simple summation process. Moreover, the recovered clean signal is free of tonal artifacts produced by methods, such as spectral subtraction.

2:00

2pSC2. Efficient spectral measures for automatic speech recognition. Douglas D. O'Shaughnessy (INRS-EMT, 800 de la Gauchetiere West, Ste. 6900, Montreal QC, Canada H5A 1K6)

It is well known that automatic speech recognition (ASR) requires good spectral analysis in order to have successful ASR accuracy. A wideband spectrogram seems to contain all the needed acoustic information to map any given speech signal into its corresponding sequence of phonemes. (For ASR, language models are often used to augment acoustics, but here we will limit ourselves to acoustic analysis.) Various methods beyond the basic Fourier transform have found success in ASR, e.g., linear predictive analysis, wavelets, and mel-frequency cepstra (MFCC). These have all been focussed on extracting an efficient set of spectral parameters to facilitate phonetic discrimination. Part of the difficulty is separating spectral envelope information from excitation parameters, as variations in pitch are largely viewed as orthogonal to phoneme recognition. Another complicating factor is that amplitude and frequency scales in speech production and perception are better modeled as nonlinear (unlike the linear, fixed-bandwidth approach of Fourier transforms). Modern ASR techniques are far from optimal, as the front-end data compression yielding MFCCs, for a basic 80-ms phoneme, typically has more than 100 parameters, to distinguish among approximately 32 phonemes (a 5-bit choice). We will investigate various ways to render ASR analysis more efficient. [Work supported by NSERC-Canada.]

2:25

2pSC3. Representing sound energy, phase, and interference using three-dimensional signals. Pantelis N. Vassilakis (De Paul Univ., 2350 N. Kenmore Ave., J. T. Richardson Library 207, Chicago, IL 60614, pantelis@acousticslab.org)

As graphic representations of vibrations/waves, sound signals capture only selected attributes of the phenomenon they represent. Assuming equivalence between signals and sound waves obscures the fact that 2-D signals are unfit to a) represent wave-energy quantities consistently across frequencies, b) account for the phase flip and alternating positive/negative amplitude values in modulated waves with AM-depth $>100\%$, and c) represent the energy content of interference. The proposed sound-signal representation is based on the complex equation of motion describing a wave. It results in spiral sine signals and twisted-spiral complex signals, similar to complex analytic signals, with the imaginary component of the complex equation of motion representing the signal envelope's argument (phase). Spiral sine signals offer a consistent measure of sine-wave energy across frequencies, while twisted-spiral complex signals account for the negative amplitudes observed in modulated signals, mapping the modulation parameters onto the twisting parameters. In terms of interference, 3-D signals illustrate that amplitude fluctuations and the signal envelopes that describe them are not just boundary curves but waves that trace changes in the total instantaneous energy of a signal over time, representing the oscillation between potential and kinetic energies within a wave. Examples of 3-D animations illustrating the proposed signals are presented.

2:50–3:00 Break

3:00

2pSC4. Inverting reassignment. Marcelo O. Magnasco (Rockefeller Univ., 1230 York Ave., New York NY 10021)

The short time Fourier transform has an extremely useful feature: its integral on vertical slices is the original signal. Thus the transform itself is explicitly invertible: we can always get back the original from the transform. Its absolute value may, under some conditions on the windowing function, be inverted as a matter of principle, though an algorithm to do so is rather unwieldy. Similarly, spectral reassignment can be shown to be invertible, as a matter of principle, under certain conditions on the reassignment operator; for instance, instantaneous time-frequency and other complex analytic operators can be inverted, in the sense that all relevant information to permit inversion is preserved; this does not mean, however, that a practical way to do so suggests itself. We shall discuss recent progress on practical algorithms which preserve phase information in reassignment to permit inversion.

3:25

2pSC5. Hidden in plain view: Analysis and synthesis of speech features from derivatives of the short-time phase spectrum. Kelly Fitz (Starkey Hearing Res. Ctr., 2150 Shattuck Ave., Ste. 408, Berkeley, CA 94704, kelly_fitz@starkey.com)

The time-frequency reassigned spectrogram has been shown to yield a clean and readable representation of the distribution of energy in speech signals. In this algorithm, precise, signal-dependent loci for time-frequency analysis data are computed from first-order partial derivatives of short-time spectral phase. In this presentation, evidence for the significance of higher-order derivatives of spectral phase will be presented along with algorithms for computing them. It will be shown that harvesting the information in the short-time phase spectrum allows the construction of an enhanced harmonic model of speech signals, having precise instantaneous frequency data for the harmonic components, and greatly reduced temporal smearing relative to traditional additive models. This enhanced model yields high-quality, artifact-free synthesis of sounds from modified and transformed time-frequency data.

Contributed Paper

3:50

2pSC6. What's wrong with these formants? Sean A. Fulop (Dept. of Linguist., California State Univ. Fresno, PB92 5245 N. Backer Ave., Fresno, CA, 93705, sfulop@csufresno.edu)

Speech is frequently modeled as an all-pole (autoregressive) linear filter applied to a voice source, commonly called Linear Predictive Coding. This model has been used for many years to provide measurements of the resonance frequencies (formants) characterizing speech sounds. That notwithstanding, it has also been well recognized that the use of this method to measure formants is very often fraught with problems, but just how serious are these problems, and can anything be done to improve upon LPC formant measurements? A few examples will demonstrate that the problems plaguing LPC formant measurements are too often intractable, and frequently yield formant values which are nowhere near the truth. For example, the voice bar will be shown to falsely lower the reported first formant value in many simple cases. It might even be suggested that reliance on this technique has impeded our understanding of exotic speech sounds which do not display a typical formant pattern. Precision formant measurements can be provided in most instances by reassigned spectrograms that have been specially processed to highlight signal components. Examples will be shown and used as benchmarks against which the LPC method can at last be properly evaluated.

Session 2pUW

Underwater Acoustics and Acoustical Oceanography: Passive Imaging and Monitoring Using Random Wavefields

Karim G. Sabra, Cochair
Scripps Inst. of Oceanography, Marine Physical Lab., 9500 Gilman Dr., La Jolla, CA 92093-0238

Martin Siderius, Cochair
Heat Light and Sound Research Inc., 12730 High Bluff Dr., Suite 130, San Diego, CA 92130

Chair's Introduction—1:00

Invited Papers

1:05

2pUW1. Travel time estimation from noisy data in random media. George Papanicolaou (Dept. of Mathematics, Stanford Univ., Stanford, CA)

We consider the estimation of Green's functions, or travel times, from noisy data when the medium is not homogeneous. In the homogeneous case travel times can be estimated from cross correlations of noisy traces at the two points between which the travel time is to be estimated, given information about the nature and extent of the noise sources. In a randomly inhomogeneous medium the noisy traces contain information not only about the homogeneous background but also about the inhomogeneities. It is shown how to assess this effect and the limits it puts on travel time estimation.

1:30

2pUW2. Monitoring dynamic matter using the mesoscopic phase statistics of random wave fields. John H. Page, Michael L. Cowan, W. Kurt Hildebrand, Tomohisa Norisuye (Dept. of Phys., Univ. of Manitoba, Winnipeg, MB, Canada R3T 2N2), Domitille Anache-Menier, and Bart A. van Tiggelen (CNRS/Universite Joseph Fourier, Maison des Magisteres, BP 166, 38042 Grenoble, France)

In strongly scattering materials, multiple scattering tends to randomize the phase of transmitted or reflected waves and, as a result, the phase has often been overlooked. In this talk, the use of phase information to monitor the dynamics of multiply scattering media will be described and illustrated through measurements of the temporal fluctuations of ultrasonic waves transmitted through a time-varying mesoscopic sample. The probability distribution of the wrapped phase difference as a function of evolution time, as well as its variance, is measured and compared with theoretical predictions based on circular Gaussian (C1) statistics. Excellent agreement is found. A fundamental relationship between the variance in the phase of the transmitted waves and the fluctuations in the phase of individual scattering paths is predicted theoretically and verified experimentally. This relationship not only gives deeper insight into the physics of the phase of multiply scattered waves, but also provides a new way of probing the motion of the scatterers in the medium. To investigate dynamics on longer time scales, we also investigate the variance and correlations of the cumulative phase. This combination of wrapped and cumulative phase measurements allows both the short and long time dynamics to be probed with excellent sensitivity.

1:55

2pUW3. Energy propagation and localization in disordered media. Kasper van Wijk (Dept. of Geosciences, Boise State Univ., 1910 Univ. Dr., Boise, ID 83712-1536, kasper@cgiss.boisestate.edu) and Matthew Haney (Alaska Volcano Observatory, Anchorage, AK 99508)

While waves in 3D random media still pose quite the challenge to use in model parameter estimation, the complicated paths of multiply scattered waves can be tracked with greater ease in 1D or quasi-1D media. Applying the model of radiative transfer (RT) to the squared waveforms, I will present results of experimental surface-wave multiple scattering, as well as numerical and theoretical aspects of energy propagation in layered media. In the case of surface-wave scattering, it is possible to estimate the average scattering and intrinsic absorption lengths in a laboratory ultrasonic experiment independently. This may be useful in partial saturated materials such as soils and rock, where intrinsic absorption is often related to the movement of fluids in the pore space. Especially in layered media, multiply scattered waves can interfere with one another. An example of strong wave interference is wave localization. Normally, diffusion and RT do not account for wave interference, but new additional terms in RT for layered media explain wave interference and localization: phenomena. Ultimately, the goal is to extend these results for parameter estimation in random media—once understood fully in lower dimensions—to three-dimensional problems.

2:20

2pUW4. Extraction of the Green's function from ambient fluctuations for general linear systems. Roel Snieder (Ctr. for Wave Phenomena, Colorado School of Mines, 1500 Illinois Str., Golden, CO 80401-1887, rsnieder@mines.edu) and Kees Wapenaar (Delft Univ. of Technol., 2600 GA Delft, The Netherlands)

The extraction of the Green's function of acoustic and elastic waves from ambient fluctuations is by now a technique that is theoretically well-described and that has successfully been used in different applications. We show theoretically that the principle of the extraction of the Green's function can be generalized to a wide class of linear systems. These new applications include the diffusion equation, Maxwell's equations, a vibrating beam, and the Schröedinger equation. For systems that are invariant for time-reversal it suffices to have sources of ambient fluctuations on a surface that bounds the region of interest. When the invariance for time-reversal is broken; as, for example, in the case of the diffusion equation or for wave propagation in attenuating media, one also needs sources of ambient fluctuations throughout the volume. This work opens up new opportunities to extract the Green's function from ambient fluctuations that include electromagnetic fields in conducting media, flow in porous media, wave propagation in attenuating media, monitoring of mechanical structures, and quantum mechanics.

2:45

2pUW5. Dispersion curves and small-scale geophysics using noise cross-correlation techniques. Philippe Roux, Pierre Gouedard, and Cecile Cornou (LGIT, CNRS 5559, Universite Joseph Fourier, Grenoble, France)

It has been demonstrated, both theoretically and experimentally, that the Green's function between two receivers can be retrieved from cross-correlation of isotropic noise records. Since surface waves dominate noise records in geophysics, tomographic inversion using noise correlation techniques have been performed from Rayleigh waves so far. However, very few numerical studies implying surface waves have been conducted to confirm the extraction of the true dispersion curves from noise correlation in a complicated sedimentary ground model. In this work, synthetic noise has been generated in a small-scale (<1 km) numerical realistic environment and classical processing techniques are applied to retrieve the phase velocity dispersion curves in the medium, first step toward an inversion. We compare results obtained from SPAC (spatial auto-correlation method) and noise correlation techniques on a ten-element array. Two cases are presented in the (1–20 Hz) frequency bandwidth that corresponds to an isotropic or a directional wavefield noise.

3:10

2pUW6. Ambient seismic noise and teleseismic tomography in the western USA: High-resolution 3-D model of the crust and upper mantle from Earthscope/USArray. Yingjie Yang, Michael Ritzwoller, Morgan Moschetti (Ctr. for Imaging the Earths Interior, Dept. of Phys., Univ. of Colorado at Boulder, Boulder, CO 80309), and Donald Forsyth (Brown Univ., Providence, RI 02912)

Short-period surface wave dispersion measurements are extremely hard to obtain from teleseismic events due to scattering and attenuation. Ambient seismic noise is rich in short-period surface waves from which the Rayleigh wave Green function between pairs of stations can be extracted by cross-correlating long noise sequences. Tomography based on surface wave dispersion obtained from the estimated Green functions has been shown to produce high-resolution, short-period (6–30 s) surface wave dispersion maps that principally image crustal geological units (e.g., southern California: Shapiro *et al.*, 2006; Europe: Yang *et al.*, 2007). In this study, we measure phase velocity dispersion curves from the ambient noise cross-correlations to obtain phase velocity maps at periods from 6 to 30 using data from the transportable array component of USArray. A two-plane-wave tomography method including finite-frequency effects was employed to obtain phase velocity maps at complementary periods from 25 to 150 using teleseismic events. The combined phase velocity data set from 6 to 150 is used to invert for high-resolution 3-D Vs structure from the surface to $\sim$ 200 km depth beneath the western USA. The new 3-D Vs model can be used to interpret regional tectonics, model seismic wave propagation, and improve earthquake location.

3:35–3:50 Break

Contributed Papers

3:50

2pUW7. Monitoring a volcano with passive image interferometry. Christoph Sens-Schönfelder[a)] and Ulrich Wegler[b)] (Universität Leipzig, Talstrasse 35, 04103 Leipzig, Germany)

Ambient seismic noise has been used successfully as a source of information for structural investigations. Ballistic surface as well as body waves were reconstructed by correlation of noise and used in tomographic studies. In these cases it is of course assumed that the medium under study is stationary, i.e., that the reconstructed Green's function does not change with time. In this contribution we show that medium changes can well be monitored by means of subtle changes in the Green's function. Using an interferometric approach applied to the coda part of the Green's function, we detect temporal changes of delay times on Merapi volcano (Indonesia). The changes of delay time depend on lapse time, which indicates that the velocity changes inside the volcano are spatially heterogeneous. We present a hydrological model that can explain the temporal changes of delay time as well as its lapse time dependence changes of the ground water level induced by precipitation. From this analysis we conclude that (a) seismic coda can be practically retrieved from noise correlations, (b) temporal changes can be monitored with noise correlations, (c) even spatial heterogeneity of the changes can be identified, and (d) the coda retrieved from noise correlations is composed body waves. [a)]Currently at LGIT Grenoble, France. [b)]Currently at SZGRF/BGR Erlangen, Germany.

4:05

2pUW8. Passive measurements of random wave fields in an instrumented structure. Karl A. Fisher, David H. Chambers, and Sean K. Lehman (Lawrence Livermore Natl. Lab., Livermore, CA 94551)

A passive measurement system using fiber Bragg gratings is presented to interrogate the health of an instrumented part. Estimation of the structures Green's function from diffuse sound fields present during typical operating conditions is the basis for our approach. Experimental studies are conducted using coherent processing techniques of random and generated sound fields to investigate a structure for defects and/or deviations from an initial or pristine state. We are interested in developing a monitoring process that is minimally invasive and robust enough to survive the environment that the structure operates in and provide a quantitative assessment of the structure throughout its lifetime.

4:20

2pUW9. Passive *in vivo* elastography from skeletal muscle noise.
Karim G. Sabra, Stephane Conti, Philippe Roux, and W. A. Kuperman (Marine Physical Lab., Scripps Inst. of Oceanogr., UC San Diego, San Diego, CA 92093-0238, ksabra@mpl.ucsd.edu)

Measuring the *in vivo* elastic properties of muscles (e.g., stiffness) provides a means for diagnosing and monitoring muscular activity: muscles typically become "harder" during contraction occurring through physiological changes. Standard elastography imaging techniques estimate soft tissue (e.g., skeletal muscle, breast) stiffness using propagating shear waves in the human body generated by an external active source (e.g., indentation techniques, ultrasonic radiation force). We demonstrated a passive *in vivo* elastography technique without an active external radiation source. This technique instead uses cross-correlations of contracting skeletal muscle noise recorded with skin-mounted sensors. The coherent arrivals emerge from a correlation process that accumulates contributions over time from noise sources whose propagation paths pass through both sensors successively. Each passive sensor becomes a virtual *in vivo* shear wave source. The results point to a low-cost, noninvasive technique for monitoring biomechanical *in vivo* muscle properties. The efficacy of the passive elastography technique originates from the high density of cross paths between all sensor pairs potentially achieving the same sensitivity obtained from active elastography methods. The application of this passive elastography technique for constructing biomechanical models of *in vivo* muscle properties will be discussed.

4:35

2pUW10. Extracting the local Green's function from ocean noise on a horizontal array.
Stephanie E. Fried, Karim G. Sabra, and William A. Kuperman (Scripps Inst. of Oceanogr., 9500 Gilman Dr, La Jolla, CA 92093-0238, sefried@ucsd.edu)

Time delays, associated with different ray paths between the elements of a bottom hydrophone array, can be extracted using ambient noise cross-correlations [Sabra *et al.*, J. Acoust. Soc. Am. **114**, 2462 (2003)]. This is confirmed using long time noise recordings that were collected in May 1995 near the S. California coast at an average depth of 21 m. The noise is mainly biological in the frequency range of 250–700 Hz [D. Spain *et al.*, J. Acoust. Soc. Am. **99**, 2453 (1996)]. The cross-correlations of noise from a horizontal array can be used to extract the local Green's function from the ocean ambient noise. [Research supported by ONR.]

4:50

2pUW11. Large-area acoustic field characterization in shallow water by using broadband ship noise measured on the New Jersey Shelf.
Altan Turgut (Naval Res. Lab., Acoust. Div., Washington, DC 20375)

Acoustic signals emitted by ships of opportunity (merchant ships) are simultaneously recorded on three vertical line arrays (VLAs) during the New Jersey Shelf RAGS03 experiment. Although the single-receiver correlation between the VLAs (separated by $\sim$10 km) was very low, a Bartlett correlator between each VLA produced well-defined striation patterns. Waveguide invariant theory has been applied to Bartlett correlator output to obtain range ratios of the noise source to the receiver arrays [A. Turgut, J. Acoust. Soc. Am. **118**, 1857 (2005)]. Trajectories of striations are identified by the Hough transform that converts a difficult global detection problem in the image domain into a simpler local peak detection problem. The striation patterns are also observed when the Bartlett correlator is applied to different time segments of the noise data. This provided an opportunity of obtaining reference acoustic field data for winter conditions if the location of the noise source is known *a priori*. Analysis of the RAGS03 data indicates the feasibility of source localization and acoustic field characterization by using broadband noise signals emitted by distant surface ships. [Work supported by ONR.]

5:05

2pUW12. Green's function retrieval through ocean acoustic interferometry.
Laura A. Brooks[a] and Peter Gerstoft (Marine Physical Lab., Scripps Inst. of Oceanogr., La Jolla, CA)

A stationary phase argument is used to describe the relationship between the stacked cross-correlations from a line of vertical sources, located in the same vertical plane as two receivers, and the Green's function between said receivers. Results and simulations which demonstrate the approach and are in agreement with those of a modal based approach used by others are presented. Results indicate that the stacked cross-correlations can be directly related to the shaded Green's function, so long as the modal continuum of any sediment layers is negligible. Preliminary results from the SWO6 experiments are discussed. [Work supported by ONR, Fulbright (sponsored by Clough Engineering), and DSTO Australia.]
[a] Also at the School of Mechanical Engineering, University of Adelaide, Australia.

5:20

2pUW13. Environmental effects on passive fathometry and bottom characterization.
Steven L. Means (Naval Res. Lab., Code 7120, 4555 Overlook Ave. SW, Washington, DC 20375, means@wave.nrl.navy.mil) and Martin Siderius (HLS Res. Inc., San Diego, CA 92130)

Recently, Siderius, Harrison, and Porter developed a method, based on the Fourier synthesis of the cross-spectral density from nearby positions, to exploit the oceans' coherent ambient noise field due to breaking waves to make measurements of the bottom and subbottom properties. During 2006 breaking wave noise measurements were made in the shallow waters (25 m) approximately 75 km off the coast of Savannah, GA on a 32-phone, three nested-aperture, vertical hydrophone array that was deployed 100 m from a Navy tower that stands 50 m above the water surface. The Skidaway Institute of Oceanography operates a suite of instruments for measurements of both atmospheric and oceanic conditions at the tower. Data were collected in a variety of environmental conditions, with wind speeds ranging from 5–21 m/s and wave heights of 1–3.4 m. The data is analyzed to quantify the performance of the passive fathometer methods as a function of the wind speeds, wave conditions, and averaging times. The results will be compared with ground-truth measurements made at the tower site prior to its construction. [Work supported by ONR base funding at NRL.]

5:35

2pUW14. Array limitations of coherent noise processing for geoacoustic inversion.
Peter Gerstoft, Chen-Fen Huang, William S. Hodgkiss (Marine Physical Lab., Univ. of California San Diego, CA 92093-0238), and Martin Siderius (Heat Light and Sound Res. Inc, CA 92130)

Ocean acoustic noise can efficiently be processed to extract Greens function information from noise [Roux *et al.*, JASA 2004, Siderius *et al.*, JASA 2006]. By crosscorrelating the ambient noise field from two sensors, it is possible to extract the impulse response between the two sensors including bottom and sub-bottom bounces if the noise field is homogenous. Since the major part of the ocean-noise is horizontal and thus strongly inhomogeneous, this processing does not extract the vertical bouncing energy well. Using array processing it is possible extracting the vertical bouncing energy. However, this beamforming-like approach can just be done for frequencies less than the array design frequency. For higher frequencies the side lobes in the beam pattern will make the horizontal energy appear as vertical and can thus not be used. Vertical velocity sensors can filter out some of this horizontal energy and a vertical velocity sensor array can be used at higher frequencies than a pressure sensor array. When this noise processing is used on a vertical array, it gives valuable information about the subbottom near the array.

Meeting of Accredited Standards Committee (ASC) S12 Noise

R. D. Hellweg, Chair, S12
Hewlett Packard Co., Acoustics Lab, MR01-2/K15, 200 Forest Street, Marlborough, MA 01752

W. J. Murphy, Vice Chair, S12
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Accredited Standards Committee S12 on Noise. Working Group Chairs will report on the status of noise standards currently under development. Consideration will be given to new standards that might be needed over the next few years. Open discussion of committee reports is encouraged.

People interested in attending the meeting of the TAG for ISO/TC 43/SC 1 Noise, take note - that meeting will be held in conjunction with the Standards Plenary meeting at 10:30 a.m. on Tuesday, 5 June 2007.

Scope of S12: Standards, specifications and terminology in the field of acoustical noise pertaining to methods of measurement, evaluation and control, including biological safety, tolerance and comfort and physical acoustics as related to environmental and occupational noise.