Session 2aAAa

Architectural Acoustics: Fostering Productive Architect—Acoustical Consultant Relationships

Scott D. Pfeiffer, Cochair
Threshold Acoustics LLC, 53 W. Jackson Blvd., Ste. 1734, Chicago, IL 60604

Molly K. Norris, Cochair
Threshold Acoustics LLC, 53 W. Jackson Blvd., Ste. 1734, Chicago, IL 60604

Chair's Introduction—8:30

This session features a panel discussion with three architects who have worked extensively in the area of performing arts, as well as other areas of architecture which have found the integration of the input of acoustics consultants beneficial. They offer three different perspectives on productive architect-acoustician relationships and what collaboration techniques they have found successful on a variety of large and small scale projects. The panel will be made up of Alan Joslin of Epstein Joslin Architects in Cambridge, Larry Kearns of Wheeler Kearns Architects in Chicago and Mark Sexton of Kruek + Sexton Architects in Chicago.

Contributed Papers

8:35

2aAAa1. An architect's perspective on acoustics. Gary Siebein (School of Architecture, Univ. of Florida, P.O. Box 115702, Gainesville, FL 32611, gsiebein@siebeinacoustic.com), Adam Bettcher, Joshua Fisher, Threcia Robinson, and Reece Skelton (Sebein Assoc., Inc., Gainesville, FL 32607)

The basis for conceptual thinking in architecture is simultaneously aesthetic, humanistic, and scientific. An architectural theory was developed that includes philosophical, aesthetic, and technical thinking about acoustics as generative ideas for form. This theory has its roots in defining an acoustic landscape or soundscape: both interior and exterior, where the soundscape is formed by the architectural ideas and the soundscape reciprocally defines the architecture. The ensuing dialogical exploration of form, space, material, occupation, and phenomenological qualities provides a basis for the mutual expression or poesis of architectural and acoustic designers. The theory was used as the basis for graduate studio design classes at the University of Florida and is presented through the work of several students.

8:50

2aAAa2. Bypassing metrics and designing holistically use of site-specific auralizations. Joshua Cushner (Arup Acoust., 155 Ave. of the Americas, New York, NY 10013)

Acoustics as a discipline has developed many objective metrics to define subjective acceptance criteria. The most common metrics used by acousticians tend to be generalized in order to communicate effectively with clients and architects at the expense of accuracy. These generic criteria can be given undue importance on a particular project when a more site-specific investigation may indicate the criteria to be inappropriate. Simply stated, standard acoustic criteria can serve to create an artificial barrier to otherwise effective solutions and strain the consultant-architect and consultant-client relationship. However, resistance from deviating from standard criteria is understandable when few nonacousticians (and even some acousticians) can appreciate the qualitative aspects of a given criteria. Providing site-specific auralizations can serve to bridge the communication gap with architects and clients by moving from a criteria-based design to a performance based design. Through the process of site evaluation and design auralization, analyses can be provided which place the client or architect directly in the subject environment, where they are able to make value-based judgments, irrespective of generic criteria. Results from recent project studies show this approach to be useful to enhance communication with the architect and provide the acoustician with another useful analysis tool.

9:05—9:10 Break

9:10—10:10 Panel Discussion

Session 2aAAb

Architectural Acoustics: Acoustical Challenges of Implementing Curtain Wall Construction

Scott D. Pfeiffer, Cochair
Threshold Acoustics LLC, 53 W. Jackson Blvd., Ste. 1734, Chicago, IL 60604

Molly K. Morris, Cochair
Threshold Acoustics LLC, 53 W. Jackson Blvd., Ste. 1734, Chicago, IL 60604

Chair's Introduction—10:25

Invited Papers

10:30

2aAAb1. Spertus Institute of Jewish Studies: Sound isolation of unique curtain wall design. Polyana Frangetto (Kirkegaard Assoc., 801 W. Adams St., 8th Fl., Chicago, IL 60607, pfrangetto@kirkegaard.com)

The case study describes the challenges encountered in designing and building the curtain wall window system of the new Spertus Institute—ten-story building in Chicago, IL, designed by Krueck + Sexton Architects, opened in November 2007. The multifaceted glass facade, overlooking Michigan Avenue into Grant Park and Lake Michigan, is formed by complex folds in three dimensions and supported by a customized structural system. Noise isolation to the urban environment and between diverse program spaces along the building's glass front such as exhibition galleries, library, administrative offices, multimedia classrooms, museum, children's center, board room, space for community events and celebrations, and café is a high priority. Innovative design details were developed to preserve the vertical sound isolation from floor to floor along the jagged slab edges and to address the horizontal sound isolation between the sloped panes of glass. This paper presents in detail the program functions, design considerations, options explored, and test results of the final solution.

10:50

2aAAb2. Luxury isolation: Curtain wall construction and the impact on the expectation of acoustic isolation. Carl Giegold and Molly Norris (Threshold Acoust., 53 W. Jackson Blvd., Ste. 1734, Chicago, IL 60604, cgiegold@thresholdacoustics.com)

Curtain wall construction is an aesthetically popular choice among architects for exterior glazing. It is often employed in luxury settings where the expectation of acoustic isolation is high, but the ability to achieve it is low. This is particularly an issue with regard to room-to-room isolation at curtain wall mullions. The author will present a case study involving the use of curtain wall construction in a high rise luxury hotel and including the issues with warranty and an alternative approach to improving the performance of these elements.

Contributed Papers

11:10

2aAAb3. Methods for reducing flanking airborne noise transmission through mullions of curtain wall systems. John LoVerde and Wayland Dong (Veneklasen Assoc., 1711 16th St., Santa Monica, CA 90404, jloverde@veneklasen.com)

Over the course of design of high-rise structures incorporating curtain wall design, there is a common limitation of the sound isolation that can be obtained at the intersection of demising partitions at the curtain wall. Approximately 45 years ago, Veneklasen Associates (VA) developed details to control the isolation. Through field testing and observations, this detailing was optimized. Approximately 15 years ago, VA constructed the intersection details in a laboratory to confirm the results from our experience. In the past 15 years, these details have further been advanced to create sound isolation in line with the desire of the user, including multifamily residential dwellings. VA shall present the historical detailing and modifications to the detailing and correlate this information with subjective and objective assessments of these constructions.

11:25

2aAAb4. Descriptors of aural connectivity: Architectural enclosure features and acoustical qualities. Selen Okcu, Craig Zimring (College of Architecture, GaTech, Atlanta, GA 30332-0155 gth678y@mail.gatech.edu), and Erica Ryherd (GaTech, Atlanta, GA 30332)

In intensive care unit (ICU) settings, auditory monitoring of alarm and nonalarm sounds is one of the key nursing functions. In the ICU sound environments there are many different noise sources, some producing more than one tone to communicate different conditions. In a sound environment with many different sound layers offering different sound qualities and sound levels nurses are expected to distinguish the sounds from each other and identify critical ones. Earlier studies showed that effective auditory monitoring requires recognition, localization, and immediate reaction to critical sounds to improve patient safety, nurse work efficiency, and reduce nurse burnout. This study explores the nurse task specific auditory monitoring experience by documenting the nurse auditory tasks and systematically mapping related sounds. This is analyzed as *aural connectivity*, a network measure that reflects the overall pattern of where users can recognize and

localize the critical sounds in architectural enclosures. It is hypothesized that enclosure types shape sound environments that affect user auditory experience. This paper defines the metrics for enclosures and associated acoustical qualities by looking at two ICU settings and discusses the preliminary results regarding the relationship between qualities of sound environment and architectural enclosures.

11:40

2aAAb5. Defining perceptual requirements of real-time acoustic auralizations. Linda Gedemer and Jonas Braasch (Dept. of Architectural Acoust., Rensselaer Polytechnic Inst., 110 8th St., Troy, NY 12180)

Acoustic modeling evolves from static sources and receivers to dynamic sources and receivers as computational speeds allow for faster renderings. Current research has focused on creating highly accurate dynamic models with the hope of producing accurate auralizations but still struggles with the trade-off between accuracy and available processing speed. The question remains as to how accurate do these models need to be if the receiver (listener) moves dynamically through the acoustic model. The focus of this paper is to address the accuracy required of dynamic models and/or auralizations from a perceptual standpoint. From this, the necessity for creating models that are perhaps more accurate than required will be considered.

TUESDAY MORNING, 11 NOVEMBER 2008 LEGENDS 2, 8:00 TO 11:50 A.M.

Session 2aAB

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

Whitlow W. L. Au, Chair
Hawaii Inst. of Marine Biology, P.O. Box 1106, Kailua, HI 96734

Chair's Introduction—8:00

Invited Papers

8:05

2aAB1. Why honor Dr. Sam H. Ridgway. William Evans (Dept. of Biological Sci., Univ. of Notre Dame, Notre Dame, IN 46556, evans1930@sbcglobal.net)

Based on my 45 year association with Ridgway, I have summarized the accomplishment of this outstanding scholar and scientist. I discuss the transition from a clinical veterinarian to an accomplished researcher and innovator. Our understanding of animal bioacoustics, especially marine mammals, has been greatly influenced by his research. This is not only true in the U.S. but also in the international community. This includes the development and use of specialized techniques in advancing our understanding of the dolphin bioacoustics. His development and use of innovative methods in understanding the dolphin sound production and the impact of high level noise on dolphin hearing are significant contributions.

8:15

2aAB2. Anatomical, electrophysiological, and histological studies of dolphin auditory system: Establishment of a theory of hearing for dolphins. James McCormick (Dept. Anesthesiology, Wake Forest Univ. School of Medicine, Winston-Salem, NC 27157-1009, dolphin-flt-int@triad.rr.com)

Wever and I at Princeton University wanted to study hearing in dolphins utilizing Wever's cochlear-potential recording method, which directly reflects the performance of the ear's mechanical system. A method of humane anesthesia for dolphins for electrophysiological studies did not exist. Preliminary studies by Ridgway with halothane anesthesia published in 1965 seemed promising and motivated me and Wever to collaborate with Ridgway. Subsequently, Ridgway and I tested and perfected the use of halothane anesthesia for dolphins. This led to a coast to coast collaboration on dolphin hearing between Ridgway at Naval Missile Center Point Mugu and me and Wever at Princeton. Ridgway shared his expertise in Marine Mammal Medicine not only with us, but with the world, and in the process he became an expert marine mammal neuroscientist. Our three way collaboration demonstrated that the dolphin hears by bone conduction, with the middle ear ossicles acting as an inertial mass relative to the sound received in the lower jaw of the dolphin—the external auditory meatus and ear drum being vestigial.

8:35

2aAB3. Sam's early work on the sea turtle. Richard Fay (Parmly Hearing Inst., Loyola Univ. Chicago, Chicago, IL 60626)

I first met Sam Ridgway in 1967 or 1968 before he had become "the dolphin doctor." He was a visiting scientist at the E.G. Wever's Laboratory at Princeton, NJ and I was a new Ph.D. student. He had already done the classic experiments on the dolphin ear with Wever, McCormick, and Palin (1970, 1971, 1972, and 1974), never to be repeated in the same way. He was there to study hearing in the sea turtle (*Chelonia mydas*) using cochlear potentials. This was also the last of these kinds of experiments on these charismatic animals. Wever was most interested at the time in the reptile ear and had a swimming pool installed at the laboratory for them. The publication that resulted was that of Ridgway *et al.* ["Hearing in the giant sea turtle, *Chelonia mydas*," Proc. Natl. Acad. Sci. U.S.A. **64**, 884–890 (1969)]. It stands as the best information we have on sea turtle hearing, with an indication of sensitivity and a frequency response function. The only better information would be a behavioral audiogram, which is yet to be done. This early chapter in Sam's career is vitally important today with respect to the setting of sound exposure criteria for fish and turtles.

8:55

2aAB4. Auditory-visual equivalence learning by marine mammals. Ronald J. Schusterman, Kristy Lindemann, and Colleen Reichmuth (Long Marine Lab., Univ.of California, 100 Shaffer Rd., Santa Cruz, CA 95060)

Forty years ago Sam Ridgway began pioneering research on the brain and sensory systems of marine mammals. Our paper honoring Sam reviews studies on the abilities of dolphins and California sea lions to integrate and classify information coming from different sensory channels in cross-modal matching-to-sample tasks. Following echoic recognition of an object, a dolphin that is permitted to investigate objects visually but not echoically can readily learn and remember that earlier reflected sound cues are related to the currently reflected light cues. A California sea lion has shown that it can also integrate auditory-visual information into something resembling equivalence classes. In these studies the sea lion was taught to relate an array of individual auditory signals (e.g., "ringing bell" and "wailing siren") to several individual members of two previously established visual equivalence classes ("numbers" and "letters"). Following the training phase it was later determined that the sea lion had knowledge of untrained transitive relationships between the auditory signals and the remaining members of the two visual equivalence classes. Such findings suggest that these marine mammals have neural pathways connecting auditory and visual associative brain areas in the construction of long lasting integrated or global representations.

9:15

2aAB5. Dolphin detection of targets as a function of angular presentation and target strength. Patrick Moore (U.S. Navy Marine Mammal Program, SPAWARSYSCEN San Diego, Code 71520, 53560 Hull St., San Diego, CA 92152), Lois Dankiewicz (SAIC, San Diego, CA 92110), David Kastak (Univ. of California, Santa Cruz, Santa Cruz, CA 95060), and Dorian Houser (Biomimetica, Santee, CA 92071)

As part of an ongoing study, bottlenose dolphin (*Tursiops truncatus*) echolocation beam steering was assessed as a dolphin performed a target detection task (4- and 7.62-cm spheres) while echolocating with its head held in a fixed orientation and monitored via underwater camera. Targets were placed approximately 4.0 m in front of the dolphin [zero degree position ($P0$)] and at 34 deg to the left and right of $P0$ (PL and PR). Echolocation clicks and echoes were digitized using a high-speed 32 channel analog-to-digital card, sampling 29 calibrated hydrophones with analog filter-amplifiers arranged in a diamond-shaped array supported in a hemispherical web in front of the animal. Using a yes-no response and a modified method of constants procedure with 0.50 target presence/absence probability, detection ability (d) and response bias (B) of the dolphin were computed for both targets at all positions. Detection thresholds (d) for the 4- and 7.62-cm spheres at $P0$, PL, and PR were 4.65, 2.08, and 2.62, and 4.08, 2.81, and 3.2, respectively. Beam characteristics were computed and beam steering was verified for this dolphin. These results also show angular detection at displacements about 8 deg farther from $P0$ than previous reports for spheres half as large.

9:35

2aAB6. Using auditory evoked potentials to measure marine mammal hearing. Paul Nachtigall (Marine Mammal Res. Program, Hawaii Inst. of Marine Biology, Univ. of Hawaii, P.O. Box 1106, Kailua, HI 96734, nachtiga@hawaii.edu)

The use of auditory evoked potential (AEP) measurements for examining the hearing of marine mammals was accelerated by the need to rapidly test hearing following sound exposures during temporary threshold shift experiments. AEP measures have allowed quick measurements of hearing following intense noise exposures of sounds ranging from filtered white noise to 53-C sonars. The refinement of AEP hearing measurements with envelope following response measures leads to comparisons between behavioral and AEP hearing thresholds. These comparisons have allowed an expansion of basic hearing measurements including measures of new species such as the white-beaked dolphin and polar bear, measures of increased numbers of the same species in order to better examine population audiogram estimates and variability, and testing of hearing of animals in the field. AEP measures have also allowed the measurement of hearing during echolocation. A false killer whale has been shown to hear its own outgoing signal 40 dB down from the same sort of signal presented directly in front of it, actively control the level of its hearing of echolocation returns in an automatic gain control of hearing, and hear sounds other than echolocation sounds 20 dB differently when it is echolocating depending on target condition.

9:55

2aAB7. Studying white whale hearing and sound production at depth: Sam H. Ridgway acoustic research in the open sea. Donald A. Carder (SPAWAR Systems Ctr. San Diego, Div. 71500, 53560 Hull St., San Diego, CA 92152-5001)

When cetacean hearing sensitivity at depth versus surface arose among anthropogenic ocean sound issues, Sam Ridgway advanced an approach using the first hearing tests of trained cetaceans in the open sea to provide an answer. Two trained white whales, *Delphinapterus leucas*, made 885 voluntary dives to a platform at depths from 5 to 300 m, stationing up to 12 min at a time to test the effects of depth on hearing and sound production. As depth increased, hearing sensitivity did not diminish, as in the aerial ears of humans and other terrestrial mammals tested in pressurized chambers. As whale hearing is unchanged by depth to at least 300 m, zones of influence on them are unaffected by depth. The whales were also trained to emit a pulse train, and then whistle to the presence of a small target. Echolocation pulses did not vary statistically in amplitude or frequency at depths between 5 and 300 m. However, the peak frequencies at the open ocean test site were at 4–40 kHz, where in San Diego Bay there were usually dual peaks at 30–80 and 100–120 kHz. Response whistles decreased in amplitude, and frequency emphasis shifted higher with a depth from 5 to 300 m.

10:15—10:30 Break

10:30

2aAB8. Temporary threshold shift: Sam Ridgway's contribution to an important and not-so-temporary line of marine mammal research. Carolyn E. Schlundt (EDO Professional Services, 3276 Rosecrans St., 1st Fl., San Diego, CA 92110, carolyn.melka@edocorp.com), James J. Finneran, and Donald A. Carder (Space and Naval Warfare Systems Ctr., San Diego, CA 92152)

When the National Research Council formed a committee in 1992 to investigate the current knowledge and need for research on the potentially harmful effects of low-frequency sound on marine mammals, Sam Ridgway embarked on a course of study that is now entering its second decade. Following the committee recommendations and with the goal of providing long-term protection of the species, Ridgway initiated the first formal investigations of temporary threshold shift (TTS) in dolphins and white whales. Key to that effort was Ridgway's development of a vocal response paradigm based on the method of free response, which allowed thresholds to be quickly estimated after noise exposure. Initial studies focused on short duration tones. Subsequent studies included single, intermittent, and impulsive sounds and have produced TTSs large enough to track growth and recovery. The resulting data reveal the effects of exposure frequency, sound pressure, duration, and temporal pattern. Recent success using auditory evoked potentials to measure TTS will enable many more subjects/species to be tested. As a result of Ridgway's pioneering work, direct data now exist to predict the effects of noise on marine mammals and to develop acoustic exposure guidelines.

Contributed Papers

10:50

2aAB9. An acoustic finite-element model to study sonar interactions with marine mammals. Gonzalo Feijoo and Kenneth Foote (Appl. Ocean Phys. and Eng. Dept., Woods Hole Oceanograph. Inst., Woods Hole, MA 02543)

A computer model based on the finite-element method (FEM) is being developed to study the interaction of sonar signals with marine mammals. This model solves the Helmholtz equation in a computational box that includes the animal and the surrounding medium, water. The FEM code has been validated with analytical solutions for the scattering of a plane wave by a fluid sphere over a range of parameters and frequencies of interest. Then it has been applied to a specimen, a 142-cm-long common dolphin (*Delphinus delphis*), and internal pressure and displacement fields were computed. The animal is represented in the computer model by a set of tissue groups whose acoustic properties, density, and sound speed are taken from the literature. The geometry of each tissue group was constructed from segmented computerized tomography images. Results are presented for harmonic signals in the 1–10 kHz frequency range. [Work supported by NOPP through ONR award No. N000140710992.]

11:05

2aAB10. Statistical analysis of acoustic propagation in beaked whale habitats. Steven E. Crocker, Eryn M. Wezensky, Glenn H. Mitchell (Naval Undersea Warfare Ctr., 1176 Howell St., Newport, RI 02841-1708), and Colin D. MacLeod (Univ. of Aberdeen, Aberdeen AB24 2TZ, United Kingdom)

Research and regulatory communities have raised questions about the influence of oceanographic conditions on propagation of midfrequency sound produced by naval sonars prior to beaked whale mass stranding events. Resolving these questions requires detailed study of acoustic properties at locations known to support beaked whale populations potentially at risk of exposure. To address these concerns, this study investigated sound propagation at two known beaked whale habitats: the North Atlantic Frontier to the west of Scotland and Sagami Gulf in eastern Japan, by computing the range dependent propagation loss for an omnidirectional 3.5 kHz signal with a source level of 235 dB *re* 1 μPa at 1 m. From this, a method was developed to reduce the three-dimensional sound field to yield a source-receiver range at which there was a high probability that a given received sound pressure level would not be exceeded. To investigate the uncertainty in data for sound speed profiles and seabed acoustic properties, the sensitivity of this method to typical variations of these factors was evaluated. Understanding the physical oceanographic properties affecting sound propagation can provide critical science for development of conservation management and mitigation practices.

11:20

2aAB11. Beaked whale detection utilizing characteristics of foraging echolocation clicks. Stephen Martin (SPAWAR Systems Ctr. San Diego, 53560 Hull St., San Diego, CA 92152-5001, steve.w.martin@navy.mil)

A technique is presented for the automatic acoustic detection of beaked whale (family *Ziphidae*) foraging echolocation clicks. The technique currently employs a three-stage process. The first stage is an acoustic detection screener that uses a submillisecond detection window. The second stage analyzes for click frequency modulation characteristic of two species of beaked whale (*Mesoplodon densirostris* and *Ziphius cavirostris*). The third stage performs temporal filtering to reduce false positives using information such as individual beaked whale interclick interval characteristics. Results from nine test files (90 min of data from US Navy instrumented test ranges AUTEC and SCORE) show good performance on eight of the nine test files. The ninth test file (short finned pilot whale) exhibited 930 (assumed) incorrect calls out of 9893 screener detections (9.4%). Over 70 000 min of data from the US Navy Pacific Missile Range Facility were also processed with third stage detections ranging from 3423 to 84 240 beaked whale click detections (depending on temporal processing utilized) from over 13×10^6 screener detections.

11:35

2aAB12. Ship strike acoustics: A paradox with a parametric solution. Edmund Gerstein, Joseph Blue (Leviathan Legacy Inc., 1318 SW 14th St., Boca Raton, FL 33486), and Steven Forsythe (U.S. Naval Undersea Warfare Ctr. Div. Newport, Newport, RI)

Marine mammals are vulnerable to ship collisions when they are near the surface. Here acoustical laws of reflection and propagation can limit their ability to hear and locate the noise from approaching vessels. Defining the physics of near surface acoustical propagation as it relates to ship noise and hearing is central to understanding and mitigating ship strikes. Field data from controlled ship passages through vertical hydrophone arrays demonstrate a confluence of acoustical factors that poses detection challenges including (i) downward refraction, (ii) spreading loss, (iii) Lloyd's mirror effect, (iv) acoustical shadowing, and (v) masking of approaching ship noise by ambient noise and distant ships. A highly directional, dual-frequency parametric sonar has been developed to mitigate these challenges and to alert marine mammals of approaching vessels. The system projector is a planar array, comprised of 45 elements, band centered to transmit a high carrier frequency along with a lower side band signal. The nonlinearity of water is used to demodulate the mixed high-frequency carrier into a lower-frequency waveform audible to both manatees and whales. The bow mounted arrays project a narrow beam directly ahead of vessels and "fill in" acoustical shadows in an effort to alert marine mammals of the approaching danger. [Work funded by the DOD Legacy Resource Management Program (Navy).]

Session 2aAO

Acoustical Oceanography and Underwater Acoustics: Attenuation Coefficient of Sediments From Low- to Mid-Frequencies

James F. Lynch, Chair
Woods Hole Oceanographic Inst., Woods Hole, MA 02543

Chair's Introduction—7:55

Invited Papers

8:00

2aAO1. Sound attenuation coefficients in sandy and silty seabottoms from low- to mid-frequency field measurements in shallow water. Ji-Xun Zhou, Xue-Zhen Zhang (Georgia Inst. of Technol., Atlanta, GA 30332-0405 and Inst. of Acoust., Chinese Acad. of Sci., Beijing 100080, China, jixun.zhou@me.gatech.edu), and Nicholas P. Chotiros (The Univ. of Texas at Austin, Austin, TX 78713-8029)

The debate on the sound speed dispersion and the frequency dependence of sound attenuation in sediments has persisted for decades, mainly due to the lack of sufficient experimental data in the low- to mid-frequency speed/attenuation transition band and the limitations of existing models. This paper analyzes and summarizes the LF measurements, conducted at 20 locations in different coastal zones around the world, that have resulted in the identification of nonlinear frequency dependence of sound attenuation in sand-silt seabottoms for a frequency range of 50–2000 Hz [Zhou and Zhang, J. Acoust. Soc. Am. **117**, 2494 (2005); **119**, 3447 (2006)]. The resultant LF sound speed and attenuation can be described equally well by the Biot-Stoll model, the Chotiros BICSQS model, and the Buckingham VGS model. However, a combination of the LF field-inverted sound speeds and attenuations with data from the SAX99 and SAX04 measurements over a broadband of 50–400 000 Hz cannot simultaneously be matched by any of these models with one set of adjustable input parameters; these models either underestimate broadband dispersion or overestimate LF attenuation. Comments on the LF field-derived data, such as "speed-attenuation coupling," are made. The possible reasons for the broadband data-model mismatch are discussed. [Work supported by the ONR.]

8:20

2aAO2. Attenuation in marine sediments: *In situ* measurements versus propagation-loss inversions. Michael J. Buckingham (Scripps Inst. Ocean., Univ. of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0238, mbuckingham@ucsd.edu)

Acoustic attenuation in marine sediments may be measured either *in situ*, from the difference in signal level at two embedded probes, or from an inversion of transmission loss in the water column. Most *in situ* measurements are performed above 10 kHz and return an attenuation that scales as the first power of frequency, whereas transmission-loss inversions are performed at lower frequencies, returning a near-square-law variation with frequency. The difference between the *in situ* and transmission-loss estimates could be due to a combination of factors, including bottom roughness, which may lead to an enhanced attenuation from the transmission-loss inversions. The nonoverlapping frequency bands of the two techniques could also account for the differences in the estimated scalings of attenuation with frequency. Thus, the attenuation could scale roughly as the square of the frequency below a few kilohertz, transitioning to a linear dependence above 10 kHz. Such behavior would be consistent with the recently developed VGS theory of acoustic propagation in saturated granular materials: the effective viscosity of the molecularly thin layer of pore fluid between contiguous grains dominates the low-frequency square-law behavior of the attenuation and the strain hardening controls the high-frequency linear dependence on frequency. [Research supported by ONR.]

8:40

2aAO3. Attenuation of shear and compressional waves in surficial sediments. Michael Richardson (Marine Geosiences Div. Naval Res. Lab. SSC, MS 39529-5004)

Recent *in situ* measurements of shear and compressional wave attenuation in sediments provide an appropriate data set to develop empirical relationships among seafloor acoustic and physical properties. Compressional wave attenuation increases with increasing mean grain size and bulk density and with decreasing porosity, whereas the relationships among shear wave attenuation and these physical properties display the opposite trends. The ratio of shear to compressional attenuation ranges from 25 to 60, with the highest values occurring in fine-grained, high-porosity sediments. Empirical relationships defined by regressions of compressional and shear wave speeds on sediment physical properties have high confidence levels. However, confidence levels for the prediction of attenuation are poor due to a combination of measurement technique, spatial variability, and presence of strong near-surface gradients.

9:00

2aAO4. On the exponential power law for low frequency attenuation in shallow water. William M. Carey (Dept. of Mech. Engrg., College of Eng., Boston Univ., 110 Cummington St., Boston, MA 02215)

A review of measured transmission over sandy bottoms has found the attenuation $\alpha(f)=\alpha(f_o)\cdot(f/f_o)^n$, $1.6\leq n\leq 1.87$ for 50 Hz$<f<$1 kHz where the reference frequency f_o is nominally 1 kHz. Since plausible theory suggests that n should be equal to 2, why are observed n values different? Calculations incorporating scattering, layering, and gradients were found not to explain this observation. The discrepancy can be explained when an additional attenuation mechanism (generated lower velocity shear waves carry energy out of the waveguide) is considered. Since the intrinsic attenuation, $\alpha_i(f)$, and the apparent attenuation due to shear wave conversion, $\alpha_{swc}(f)$, are small, the observed attenuation can be $\alpha(f)\approx\alpha_{swc}(f)+\alpha_i(f)$. If the removal of energy by shear wave conversion is comparable to the intrinsic attenuation at the lower frequencies but less than the intrinsic attenuation at the higher frequencies, the inferred frequency dependence can be less than quadratic. Inversions with fluid sediments account for this effect by the use of a site-specific n factor that accounts for the loss of energy from the compressible field due to shear wave conversion. Furthermore the knowledge of $c_s(f,z)$ is required and may necessitate new methods to measure this property of sediments.

9:20

2aAO5. The physical mechanism (viscosity related) of low-frequency acoustic wave attenuation in sandy/silty sediments. Allan D. Pierce (Dept. of Mech. Eng., Boston Univ., Boston, MA 02215, adp@bu.edu)

Considered saturated sediments contain diverse rock pebbles (characteristic size of 0.1 mm). The weight of higher pebbles holds lower pebbles in contact sufficiently that acoustically induced solid displacements vary slowly over several adjacent pebbles. Apart from contact areas, each is nearly surrounded by water at a nearly uniform pressure. An appropriate first approximation predicts that the elastic stress tensor in the pebbles is diagonal, with components equal to the negative of the acoustic pressure in the neighboring fluid. The assumptions of Mallock and Wood apply: the mass weighted local average velocity is proportional to the negative gradient of the pressure in the water. The no-slip condition at the interfaces tends to force the water to move with the pebbles, but the finite viscosity allows the fluid at small distances from the interfaces to move at a different velocity than the pebbles. The apparent driving force for the oscillations of the interstitial water relative to the pebbles is associated with the inertia of the water and is proportional to the difference in densities. The derived approximate wave equation predicts attenuation proportional to frequency squared, proportional to the square of the difference of the densities, and inversely proportional to viscosity. The derived dimensionless proportionality constant is consistent with recent experiments.

9:40

2aAO6. Low- to mid-frequency model of attenuation and dispersion. Nicholas P. Chotiros, Marcia J. Isakson (Appl. Res. Labs., The Univ. of Texas at Austin, TX 78713-8029, chotiros@arlut.utexas.edu), Ji-Xun Zhou (Georgia Inst. of Technol., Atlanta, GA 30332-0405), and David P. Knobles (The Univ. of Texas at Austin, Austin, TX 78713-8029)

A model of attenuation and sound speed in ocean sediments in the low- to mid-frequency range is presented. It is based on a combination of the Biot–Stoll and contact squirt and shear drag model [Chotiros and Isakson, J. Acoust. Soc. Am. **116**, 2011–2022, (2004)] and the frame virtual mass model [Chotiros and Isakson, J. Acoust. Soc. Am. **121**, EL70 (2007)]. This combination can match measured sound speeds below Wood's equation lower bound and it addresses issues related to the Kramers–Kronig relationship. It is able to match both the sound speed dispersion and attenuation measurements from a large number of sites, including the sediment acoustics experiments (SAX99 and SAX04) in the Gulf of Mexico, the shallow water experiment on the Atlantic coast, and the Yellow Sea [Zhou, J. Acoust. Soc. Am. **78**, 1003–1009 (1985)]. [Work supported by ONR, Ocean Acoustics.]

10:00—10:15 Break

Contributed Papers

10:15

2aAO7. Measurements of attenuation of sound in marine sediments at low frequencies. Ross Chapman and Yong-min Jiang (Univ. of Victoria, Victoria, BC V8W 3P6, Canada)

This paper describes an experimental technique for measuring the attenuation of sound in marine sediments at low frequencies. The method makes use of the signals from sub-bottom reflectors that are received on a vertical hydrophone array at close ranges in shallow water environments. The signal path geometry is determined from an inversion of the travel time differences of the sea bottom and sub-bottom reflected paths to estimate the sediment sound speed and the depth of the sub-bottom reflector. The method is applied to data from experiments carried out at a site on the New Jersey continental shelf in the Shallow Water 06 experiment. The sediment type and the structure of the sediment column were ground truthed by independent measurements at the site. The chirp signal was transmitted in two frequency bands, from 100–900 and 1500–4500 Hz, and the data were match filtered to obtain the multipath signals at the array. A prominent signal from a sub-bottom interface known as the *R*-reflector was resolved in the data for each frequency band. Results are presented for the average attenuation over the depth to the reflector. [Work supported by ONR Ocean Acoustics.]

10:30

2aAO8. Wide-band attenuation measurements in New Jersey Shelf sediments. Altan Turgut (Acoust. Div., Naval Res. Lab., Washington, DC 20375, turgut@nrl.navy.mil)

The frequency dependence of attenuation in marine sediments is investigated using *in situ* measurements from a wide-band acoustic probe system during the Shallow Water 2006 (SW06) experiment. Direct-path pulse propagation measurements within the 10–80 kHz frequency band show linear frequency dependency of attenuation in dB/m at two silty-sand sites on the New Jersey Shelf. The measurements also show evidence of mild velocity dispersion within the 10–80 kHz frequency band. The measured attenuation and velocity dispersion curves are in good agreement with those predicted by an extended Biot theory for sediments with a distribution of pore sizes [Yamamoto and Turgut, J. Acoust. Soc. Am. **83**, 1744–1751 (1988)]. Attenuation roll-off measurements (dB/m kHz) were also conducted within a 3–8 kHz frequency band using a chirp-sonar subbottom profiler. The comparable levels of attenuation roll-off are observed from the chirp sonar and acoustic probe measurements. [Work supported by ONR.]

10:45

2aAO9. Laboratory measurements of sound speed and attenuation in water-saturated artificial sediments as a function of porosity. Theodore F. Argo, IV, Matthew D. Guild, Preston S. Wilson (Mech. Eng. Dept. and Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX 78712-0292), Charles Radin, Matthias Schröter, and Harry L. Swinney (Univ. of Texas at Austin, Austin, TX 78712-0264)

Several models have been proposed to describe the sound speed and attenuation of acoustic waves in water-saturated granular sediments. The difference between the predictions of competing models can be only a few percent, and it is difficult to obtain both sufficient knowledge of the sediment physical parameters and sufficiently small measurement uncertainty to adequately verify competing models. Furthermore, the inhomogeneity of natural sediments causes additional measurement and interpretation uncertainty. Therefore, well-controlled laboratory measurements are useful for model validation and also facilitate exploration of the effects of sediment physical parameter variation. A method for controlling the porosity of an ensemble of water-saturated granular particles [Schröter *et al.*, Phys. Rev. E **71**, 030301(R) (2005)] was used to prepare columns of artificial sediments, composed of monodisperse 280-μm-diameter glass spheres and distilled water of varying porosity. Acoustic time-of-flight measurements were used to determine the phase speed and attenuation of the material for frequencies from 250 to 800 kHz and for porosities from 0.37 to 0.43. The sound speed and attenuation measurements will be presented and compared to existing model predictions. [Work supported by ONR and the Robert A. Welch Foundation.]

11:00

2aAO10. Sound speed and attenuation in the sea bottom from broadband sound propagation in the Yellow Sea. Lin Wan, Ji-Xun Zhou, and Peter Rogers (School of Mech. Eng., Georgia Inst. of Technol., Atlanta, GA 30332, lin.wan@gatech.edu)

A joint China-U.S. underwater acoustics experiment was conducted in August, 1996 in 75-m water in the Yellow Sea with a very flat bottom and a strong and sharp thermocline. Broadband explosive sources were detonated both above and below the thermocline along two radial lines and a quarter of circle. Two inversion schemes are used to obtain the sound speed in the bottom. The first scheme is based on extracting normal mode depth functions from the cross-spectral density matrix (CSDM). The CSDM is constructed from explosive signals measured using a 32-element vertical line array at a fixed long range. In the second scheme, the modal arrival times are extracted using an adaptive time-frequency analysis technique. The inverted bottom sound speed is used as a constraint on high-quality TL data to extract the bottom sound attenuation. The inverted bottom attenuation exhibits apparent nonlinear frequency dependence over a frequency range from 80 to 1260 Hz. A possible effect of mode-coupling on the inverted bottom attenuation is discussed. Measured TL as a function of frequency, range, and depth is in good agreement with the predictions based on the inverted bottom acoustic parameters. [Work supported by ONR.]

11:15

2aAO11. Measuring grain roughness for the purpose of high-frequency acoustic modeling. Kevin Briggs, Allen Reed (Seafloor Sci. Branch, Naval Res. Lab., Stennis Space Ctr., MS 39529, kbriggs@nrlssc.navy.mil), Richard Ray and Michael Richardson (Naval Res. Lab., Stennis Space Ctr., MS 39529)

Grain roughness and packing are important sediment properties for newer acoustic models. We present the scanning electron stereomicroscopic imagery of natural sand grains of varying shape and roughness for evaluation of potential grain interactions of individual grains. The grain shape and the presence of microasperities will determine the probability of the contact with surrounding grains being a point or a larger area. Moreover, the use of a micro-roughness power spectrum in characterizing the sand grain roughness may be appropriate. Grain contact information is an essential starting point for developing and evaluating acoustic models that address acoustic losses at high frequencies. This information provides the basis to understand contact mechanics, such as grain slip and frame dilation, during insonification. Because media frame stiffness depends, at the grain scale, on the number and type of grain-to-grain contacts, we characterize sand sediments with imagery identifying such grain contact information. The natural shapes of grains, their variations, and their packing density present a broad distribution of grain contact types and areas. X-ray microfocus computed tomography captures volumetric images of grain interactions, which enable the grain contacts to be classified and quantified. The method and results of this evaluation with computed tomography will be also presented.

11:30

2aAO12. Measurements of sound speed and attenuation for six kinds of water saturated glass beads. K. Lee and W. Seong (Dept. of Ocean Eng., Seoul Natl. Univ., Seoul, Korea, nasalkh2@snu.ac.kr, wseong@snu.ac.kr)

Acoustic measurements of sound speed and attenuation were made in a laboratory water tank containing water saturated granular medium consisting of six kinds of glass beads each with mean grain sizes of 0.090, 0.150, 0.354, 0.507, 0.625, and 0.875 mm for several frequencies extending from 40 kHz to 1 MHz. Cross-correlation technique and time-of-flight technique are used to calculate the sound speed and attenuation of samples. In the presentation, the uncertainties of sediment preparation such as air-removal, grain packing, and depth-varying of sediment will be mainly discussed. Also, the observed patterns of the sound speed and attenuation will be presented for the mean grain size, grain size distribution, and frequency.

Session 2aMU

Musical Acoustics: Dynamical Approaches in the Study of Music Perception and Performance III

Edward W. Large, Chair
Florida Atlantic Univ., Ctr. for Complex Systems, 777 Glades Rd., Boca Raton, FL 33431

Chair's Introduction—8:30

Invited Papers

8:35

2aMU1. Dynamic encoding of pitch, timing, and timbre. Nina Kraus (Commun. Sci., Northwestern Univ., 2240 Campus Dr., Evanston, IL 60208, nkraus@northwestern.edu)

The perception of music depends on three fundamental elements: pitch, timing, and timbre. It is possible to access the neural transcription of these elements objectively, noninvasively, and with great fidelity with scalp electrodes in humans. The effects of musical experience on subcortical encoding of sound are pervasive and extend beyond music to the domains of language and emotion. The acoustic cues relating to pitch, timing, and timbre have distinct representations, which can be selectively enhanced or degraded in different populations. Musically trained subjects have enhanced subcortical representation of pitch, timing, and timbre, although with increased stimulus complexity, timbre cues become more pronounced while pitch cues are diminished. Musical experience fundamentally shapes auditory processing that occurs early in the sensory processing stream. This top-down influence is likely mediated by the extensive (corticofugal) circuitry of descending efferent fibers that synapse all along the auditory pathway. Sensory shaping occurs not only with lifelong experience but can be effected by short-term training. I will discuss a series of experiments demonstrating the lifelong and short-term malleability of the neural encoding of pitch, timing, and timbre in the auditory brainstem. [Work supported by National Institutes of Health (R01DC001510) and National Science Foundation (NSF 0544846).

9:05

2aMU2. Nonlinear dynamics approach to pitch perception and harmony. Julyan H. E. Cartwright (Instituto Andaluz de Ciencias de la Tierra, CSIC-Universidad de Granada, E-18071 Granada, Spain), Diego L. Gonzalez (FSSG-CNR, I-30124 Venezia, Italy), and Oreste Piro (Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain)

For perception, the brain handles and reacts to an enormous amount of information from the senses in real time. The question of how all this information is represented and processed within the nervous system is addressed by the nonlinear and complex system researches through the proposal that dynamical attractors may form the basis of neural information processing. Sometimes, this rather qualitative approach to modeling provides very accurate quantitative predictions. Here we show an example where this idea can be successfully applied in the human auditory system to describe and, perhaps, explain the nature of some phenomena in the perception of pitch. We will also discuss possible implications of this approach to the theory of harmony.

9:35

2aMU3. Time-frequency transformation by arrays of neural oscillators: Implications for musical structure. Marc Velasco and Edward Large (Ctr. for Complex Systems, Florida Atlantic Univ., Boca Raton, FL 33431)

A growing body of evidence is consistent with the possibility of nonlinear oscillation in both the peripheral and central auditory nervous systems. This talk will introduce a model of nonlinear time-frequency transformation via an array of neural oscillators, each tuned to a distinct frequency, organized along a frequency gradient. Transformation of sound stimuli by neural oscillators is characterized. Predictions about general properties of nonlinear time-frequency transformation, such as frequency detuning and higher-order resonance, are derived. The model is consistent with nonlinear resonance approaches to pitch perception. The perception of tonality is predicted as a global pattern of resonance regions at small integer ratio frequency relationships. Neural oscillation provides a substantive potentially universal principle underlying the basic materials of music, namely, pitch and tonality. [Work supported by AFOSR FA9550-07-C0095.]

10:05—10:30 Break

10:30

2aMU4. Dynamics of tonality. Petr Janata (Ctr. for Mind and Brain, UC Davis, 267 Cousteau Pl., Davis, CA 95618, pjanata@ucdavis.edu)

As listeners of western tonal music, we establish mental representations of tonal space: the distance relationships between major and minor keys (tonal centers). Evidence for the distance relationships underlying tonal space derives from music theory, cognitive psychology, and statistical learning approaches. Tonal space is represented parsimoniously on the surface of a torus. Although the torus itself is a static structure, the movements of music about its surface are shaped by the nuances of melodies and harmonic progressions

that mold the sense of the tonal center through time. Central to an understanding how our brains interact with music's dynamic movements in tonal space, and the main aspect of this presentation, is a consideration of the timescale(s) over which the movements are modeled. At long timescales, movements on the toroidal surface are slow and perhaps tend to reflect symbolic music-theoretic descriptions in which a series of stable tonal centers is established. When biased toward shorter timescales the toroidal dynamics reveal much livelier movement that depends on the tonal content of individual chords. Intermediate timescales reveal tonal dynamics between these two extremes, both stability and rapid transitions, and perhaps reflect the scale that most closely match our sense of tonal movement.

Contributed Papers

11:00

2aMU5. Operator algebra and coherent states for equally tempered scales. Alpar Sevgen (Dept. of Phys., Bogaziçi Univ., Bebek, Istanbul 34342, Turkey, sevgena@boun.edu.tr)

The algebra that the equally tempered scales obey is $[S_z,S_\pm] = \pm c_1 S_\pm$ and $[S_\pm,S_-] = 0$, where all are modulo N relations, and c_1 is the generator of the scale labels. The coherent states $|\lambda,\mathbf{n}\rangle$ are eigenvectors of S_- with eigenvalues λ and where $\lambda^N = 1$. Similarities and differences between these equations and the quantum mechanical angular momentum algebra are discussed. The mean square variation $\delta S_z^{\,2}$ in a coherent state depends on M, the number of notes in the scale. $\delta S_z^{\,2}$ is minimum for $M = 8$, and the next higher $\delta S_z^{\,2}$ value belongs to the customary $M = 7$. The same conclusions hold true also for the complementary scales with $M' = N - M$ notes. Thus, one may speculate about the possibility of using $M = 8$ and $M = 4$ tones in the $N = 12$ semitone equally tempered scales in musical compositions.

11:15

2aMU6. The speech-to-song illusion. Diana Deutsch, Rachael Lapidis, and Trevor Henthorn (Dept. of Psych., Univ. of California, San Diego, La Jolla, CA 92093)

This paper reports the first formal investigation of a surprising illusion: A particular spoken phrase is made to be heard convincingly as sung rather than spoken, simply by repeating it several times over. Three groups of 18 subjects each listened to the spoken phrase repeated ten times, and they judged after each repetition whether, and how strongly, they heard the phrase as spoken or as sung. For all groups, the first and last repetitions were identical. For the first group, the intervening repetitions were also identical. For the second group, the intervening repetitions were transposed upward and downward slightly (by 2/3 semitone and 1 1/3 semitone), so that the pitches differed but the pitch relationships were preserved. For the third group, the intervening repetitions consisted of the untransposed syllables presented in jumbled orders. Comparing the first with the last repetition, a clear and highly significant transition from perceived speech to perceived song occurred when the intervening repetitions were exact, but not when the intervening repetitions were transformed. This indicates that both the exact pitches and the exact pitch contours need to be repeated for the illusion to occur. This paper is accompanied by sound demonstrations of the illusion.

TUESDAY MORNING, 11 NOVEMBER 2008 LEGENDS 1, 8:45 A.M. TO 12:00 NOON

Session 2aSC

Speech Communication: James J. Jenkins: Teacher, Mentor, Researcher

Winifred Strange, Chair
CUNY Graduate School, Speech, Lang. and Hearing, 365 Fifth Ave., New York, NY 10016

Chair's Introduction—8:45

Invited Papers

8:50

2aSC1. Hearing impairment and speech communication handicap: Deconstructing the Tower of Babel. Sigfrid Soli (Dept. of Human Commun. Sci. and Devices, House Ear Inst., 2100 W. 3rd. St., Los Angeles, CA 90057)

This presentation brings together a body of international research focused on a common problem, the effects of noise on speech communication in normally hearing and hearing impaired individuals. My research on the problem is infuenced by Jim's emphases on interdisciplinary research, measurement, and importance of a good practical problem. The challenges of objectively measuring speech communication handicap are well known and longstanding. The subject research embodies an approach to this problem based on a set of principles that provides a quantitative methodology for equivalent assessment of speech communication handicap in any language. Our approach is based on the earlier work of Stevens and Plomp, as well as Plomp's model of speech communication handicap, which expresses handicap quantitatively as the elevation of the speech reception threshold (SRT) in quiet and/or noise over that of a normally hearing individual (normals). The performance of normals provides a normative reference that is functionally equivalent across languages. Elevation of the SRT above the norm for a language defines a quantitative measure of handicap with the same meaning for each language. Our research has led to the creation of SRT-based measures of handicap in 16 languages. Examples of these measures and their use in clinical outcomes research, device development, and occupational health will be given.

9:15

2aSC2. Revisiting "Acoustic information for objects, places, and events". Valeriy Shafiro (Dept. Commun. Disord., Rush Univ. Medical Ctr., 600 S. Paulina, 1015 AAC, Chicago, IL 60612)

Over two decades ago, Jenkins proposed a broad taxonomy of acoustic information which addresses the perception of objects, places, and events in the world around the listener [J.J. Jenkins "Acoustic information for objects, places, and events," *Persistence and Change: Proceedings of the First International Conference on Event Perception*, edited by W. H. Warren and R. E. Shaw, Erlbaum, (2006)]. Although lesser known than some of his other publications, this chapter has anticipated several future directions in auditory research by asking what is being perceived by the listener and why. Inspired by this taxonomy, our research on environmental sound perception by normal-hearing and cochlear implant listeners has investigated how objects and events are perceived when sensory input is degraded. Experiments with vocoded environmental sounds of varying spectral resolution indicate large differences among individual sounds in the amount of spectral resolution required for identification. Temporally patterned sounds generally need a lower spectral resolution than harmonically rich sounds. However, with training, perception of environmental sounds can substantially improve and generalize to novel sounds, potentially including speech. Findings in cochlear implant listeners further indicate strong correlations between speech and environmental sound perception abilities, suggesting a considerable overlap in the perception of these two ecologically significant sound classes.

9:40

2aSC3. Studies of speech perception: A mentor's influence. Joanne L. Miller (Dept. of Psych., Northeastern Univ., Boston, MA 02115)

A major focus of my research program has been the nature of phonetic categorization. Many of our early studies examined the locations of boundaries between phonetic categories and the kinds of contextual factors that alter boundary locations. Later, as it became increasingly clear that phonetic categories are internally structured, with some category members more representative than others, we extended our efforts to specify the nature of this internal structure and the contextual factors that fine-tune it. Most recently, we have been investigating how these internally structured context-dependent categories might be customized for the systematic acoustic-phonetic variation in the speech of individual talkers. In this presentation, I will provide examples of our findings and drawing from studies of speech perception in adults and infants. Of particular relevance, I will point out how the many important lessons I learned in graduate school from Jim Jenkins, one of my mentors, have influenced my approach to speech research over the years. [Work supported by the NIDCD.]

10:05—10:15 Break

10:15

2aSC4. Adventures of a J. J. Jenkins student in speech technology research. Ann Syrdal (ATT Labs. Res., 180 Park Ave., Rm D159, Florham Park, NJ 07932-0971, syrdal@research.att.com)

Two of the most valuable lessons I learned from Jenkins were (1) to focus on what interests me and explore why it interests me and (2) that an experiment with unexpected results can be more valuable than one that confirms the hypothesis. My graduate student years in Minnesota at the Center for Research in Human Learning, which Jenkins directed, were an exciting and revolutionary time, both on a large societal scale and academically. Experimental psychology at Minnesota had been a bastion of behaviorism and learning theory. Jenkins was our fearless leader in advancing the revolutionary ideas and emerging paradigms of cognitive psychology and psycholinguistics. In this new field, it was now possible to be scientifically rigorous and to study mental as well as behavioral phenomena. Jenkins and co-workers who played a role in my education at Minnesota have influenced both my earlier academic research and my research in speech technology over the past 22 years. After a brief overview of how I as an experimental/cognitive/perceptual/psycholinguist contributed to several speech technology projects, my talk will focus on unit selection text-to-speech synthesis and how studying and modeling the perception of speech is central to the technology.

10:40

2aSC5. What the eyes can tell us about spoken-language comprehension. Andrea Weber (Max Planck Inst. for Psycholinguistics, Wundtlaan 1, 6525 XD Nijmegen, The Netherlands, andrea.weber@mpi.nl)

As an academic great-grandchild of Jim, I had the fortune to have Jim's personal advice during the last stages of my graduate studies and during my first steps as a postdoctoral researcher. I was inspired by his great expertise, his respectful and sage comments on my work, and his encouragement for collaboration across disciplines. This paper pays tribute to Jim Jenkins by showing how his mindset influenced my own research in the field of spoken-language comprehension. In particular, I will introduce work that investigates the intersection of lower- and higher-processing levels using eye movements. Eye movements to displayed objects are tightly linked to spoken-language comprehension and are commonly used in psycholinguistic research to gain insights into underlying processes. I will present evidence for how difficulties on the perceptual level of processing can affect lexical processing and how, in turn, sentence processing can be influenced by characteristics of the lexical level, such as lexical frequency.

11:05

2aSC6. Speech perception within a biologically realistic information-theoretic framework. Keith R. Kluender (Dept. of Psych., Univ. of Wisconsin, 1202 W. Johnson St., Madison, WI 53706, krkluend@wisc.edu)

Fundamental principles that govern all perception, from hair cell to cortex, are shaping our understanding of the perception of speech and other familiar sounds. Following modest presentation of historical and philosophical background, I will explain how ecological and sensorineural considerations encourage an information theoretical approach to speech perception. Information theory and biology of sensorineural systems are emphasized in explanations of classic characteristics of speech perception, including perceptual resilience in the face of degradation, signal variability, segmentation, and categorical perception. Experimental findings will be used to illustrate how a series of like processes operate on the acoustic signal with increasing levels of sophistication on the way from wave forms to words. Common to these processes are ways that perceptual systems absorb predictable characteristics of the soundscape, from temporally local to extended periods (learning), and new information (change) is enhanced. [Work supported by NIDCD.]

11:30—12:00 Panel Discussion

TUESDAY MORNING, 11 NOVEMBER 2008 LEGENDS 12, 8:00 TO 11:55 A.M.

Session 2aSP

Signal Processing in Acoustics, Underwater Acoustics, Architectural Acoustics, and Biomedical Ultrasound/ Bioresponse to Vibration: Recent Developments in Coded Signals in Acoustics

David C. Waddington, Chair
Univ. of Salford, Acoustic Research Ctr., Newton Bldg., Salford, M5 4WT, UK

Chair's Introduction—8:00

Invited Papers

8:05

2aSP1. The use of coded signals in the measurement of diffusing surfaces. Peter D'Antonio (RPG Diffusor Systems, Inc., 651-C Commerce Dr., Upper Marlboro, MD 20774, pdantonio@rpginc.com) and Trevor Cox (Univ. of Salford, Salford M5 4WT, UK)

Following the introduction of quantifiable number theoretic, reflection phase grating diffusing surfaces by Schroeder [J. Acoust. Soc. Am. **57**, 149–151 (1975)], several approaches have been used to measure and characterize them. In the early 1980s, time delay spectrometry, developed by Heyser, was used to measure the temporal, spatial, and spectral responses of diffusing surfaces. Once maximum length sequences were introduced as an excitation signal, they were adopted in the late 1980s. These explorations led to the creation of a measurement standard for the diffusion coefficient, which is the circular autocorrelation of the third octave polar responses. The limitations of periodic number theoretic surfaces, namely, bandwidth, grating lobes, and flat plate effects, were addressed by computer optimization, which combined the power of boundary element and multi-dimensional minimization techniques, and modulation. Both one-dimensional (phase variation in one direction) and two-dimensional (phase variation in two orthogonal directions) surfaces were characterized. The data collection and reduction procedures will be reviewed with several examples of diffusing surfaces. A summary of this research can be found in the work of Cox and D'Antonio [*Acoustic Absorbers and Diffusers: Theory, Design and Application* (Spon, 2004)].

8:25

2aSP2. Improving biomedical ultrasonic imaging systems through coded excitation and pulse compression. Michael Oelze and Jose Sanchez (Dept. of Elec. and Comput. Eng., Univ. of Illinois at Urbana-Champaign, 405 N. Mathews, Urbana, IL 61801)

Coded excitation and pulse compression techniques are being employed in biomedical ultrasonic imaging systems in order to improve image quality. Traditionally, the rationale for using coded excitation techniques in biomedical ultrasonic imaging was to increase the signal-to-noise ratio (SNR) of backscattered signals without increasing the pressure amplitudes above the thresholds predicted to produce bioeffects. Furthermore, coding schemes combined with pulse compression would allow the spatial resolution to be preserved. Recently, unique coded excitation schemes have been developed [i.e., the resolution enhancement compression (REC) technique] that not only produce a significant increase in SNR but also a doubling of the bandwidth of the ultrasonic imaging system. In conventional ultrasound *B*-mode imaging, the increased bandwidth provided by the REC technique could be used to improve the axial resolution of the ultrasonic imaging system or traded off to improve the contrast resolution of the ultrasonic imaging system through frequency compounding. In quantitative imaging techniques using spectral analysis (e.g., scatterer size imaging), the increased bandwidth from REC could be used to increase the trade-off between spatial resolution and estimate variance. An overview of these coded excitation techniques and their application to biomedical ultrasonic imaging will be presented. [This work is supported by NIH EB006741.]

8:45

2aSP3. Coded signals: A challenge for acoustic wind profiling. Sabine von Hünerbein (School of Computing, Sci. and Eng., The Univ. of Salford, Salford M5 4WT, UK, s.vonhunerbein@salford.ac.uk) and Stuart Bradley (Univ. of Auckland, Private Bag 92019, Auckland, New Zealand)

Use of coded signals for acoustic wind profiling presents special challenges because the scattering mechanism is highly bandwidth-sensitive. We outline the physical principles involved and show that the signal coding methods commonly used for underwater acoustics or for transmission in the atmosphere (such as for tomography) do not apply for scattering of sound by turbulence. The degree of detuning and loss of signal strength is examined for FM chirps, in relation to the corresponding increase in signal-to-noise ratio (SNR) from matched filters. The optimum bandwidth does not give a large improvement in SNR for this physical situation. The alternative, and very conventional, use of stepped frequency chirps is examined in comparison. This too requires special consideration as to the length of each constant-frequency part. Finally, we give some insight into future developments using a combination of these approaches.

9:05

2aSP4. Annular-array 35-MHz chirp imaging applied to biomedical studies. Jonathan Mamou (F. L. Lizzi Ctr. for Biomedical Eng., Riverside Res. Inst., 156 William St., New York, NY 10038, mamou@rrinyc.org), Orlando Aristizábal (New York Univ. School of Medicine, New York, NY 10016), Jeffrey A. Ketterling (Riverside Res. Inst., New York, NY 10038), Ronald H. Silverman (Weill Medical College of Cornell Univ., New York, NY 10021), and Daniel H. Turnbull (New York Univ. School of Medicine, New York, NY 10016)

High-frequency ultrasound (HFU) is an attractive means of obtaining fine-resolution images of biological tissues for ophthalmologic, dermatological, and small-animal applications. Nevertheless, even with current improvements in circuit designs and high-frequency equipment, HFU suffers from two limitations. First, HFU images have a limited depth-of-field (DOF) because of the short wavelength and the low-fixed *F*-number of HFU transducers. Second, HFU is usually limited to shallow imaging because of significant attenuation in tissues. Previously, a 17-MHz five-element annular array was excited using chirp-coded signals and a synthetic-focusing algorithm was used to form images. Results demonstrated significant increase in DOF and penetration depth. In the present study, the same approach was implemented with 35-MHz five-element annular arrays. Vitreous-hemorrhage-mimicking phantom was imaged. Chirp images of a phantom showed increased sensitivity compared to conventional monocycle images and blood droplets into the phantom could be visualized 4 mm deeper. Three-dimensional datasets of 12.5-day-old-mouse-embryo heads were also acquired *in utero* using chirp and conventional excitations. Synthetically focused images were formed and the brain ventricles were segmented and reconstructed in three dimensions. Significant artifacts for the ventricle volumes were observed with the conventional imaging technique but were not apparent on the chirp-based dataset reconstruction. [Work supported by NIH Grant No. EB006509.]

9:25

2aSP5. Orthogonal coding sequences for multiple-source study of outdoor noise propagation. David Waddington and Jamie Angus (Acoust. Res. Ctr., Univ. of Salford, Salford M5 4WT, UK, d.c.waddington@salford.ac.uk)

This paper describes recent developments in the design of a coded acoustic signal for the study of outdoor sound propagation. Low signal-to-noise ratio is a common limitation in outdoor propagation investigations, and time variance of the air limits the amount of averaging. Recent work by the authors presented a coded acoustic signal approach consisting of a frequency carrier biphase-modulated by a specially designed pseudorandom code sequence to overcome these limitations. The "inner and outer" code sequence was specially designed for environmental sound propagation investigations, combining simultaneous fine time resolution and large range ambiguity, together with an ability to average and probe the propagation path. This approach is extended to multiple acoustic sources for the study of outdoor sound propagation, with the design of signals using orthogonal correlation sequences. The results illustrate that combinations of orthogonal coding and multiple carrier frequencies can permit continuous sound speed measurements in numerous vertical and horizontal directions and might therefore be useful for acoustic tomographic applications.

9:45—10:00 Break

10:00

2aSP6. Multimodal coded excitation in medical ultrasonic imaging. Yayun Wan and Emad Ebbini (Dept. of Elec. and Comput. Eng., Univ. of Minnesota, 200 Union St. SE, Minneapolis, MN 55455, wanx0028@umn.edu)

Coded excitation has been used successfully in medical ultrasound to improve the signal to noise ratio and penetration depth. Furthermore, inverse filtering techniques have been shown to improve axial resolution without significant loss in contrast due to the range sidelobe phenomenon. With the next generation ultrasound scanners, the opportunity exist for transmitting multiple codes simultaneously, with or without focusing, into the region of interest. Using appropriate 2D inverse filtering on receive, it is possible to control the axial and lateral resolutions of the imaging system while maintaining an acceptable tradeoff with image contrast. In this paper, we review recent results on 1D and 2D inverse filtering of beamformed echo data resulting from insonification of speckle-generating cyst phantoms with multiple codes. We demonstrate that (regularized) inverse filtering can be derived from the space-time array patterns. Furthermore, we demonstrate the feasibility of reconstructing multiple image lines in parallel to increase the frame rate in 2D and 3D imaging.

10:20

2aSP7. Pseudorandom sequences for binary amplitude diffusers. Konstantinos Dadiotis, Jamie A. S. Angus, and Trevor J. Cox (Acoust. Res. Ctr., Univ. of Salford, Salford M5 4WT, UK, k.dadiotis@pgr.salford.ac.uk)

Binary amplitude diffusers create a mixture of absorption and diffusion and are used to improve room acoustic conditions. They require a two dimensional binary pseudorandom array to state where absorbing and reflecting patches should be. Consider the binary array to have dimensions $A \times B$. Ideally, A and B should be similar to maximize performance. Such an array can be produced by folding a one dimensional sequence into a two dimensional array using the Chinese Reminder Theorem. This theorem requires A and B to be coprimes. However, there is a limited set of optimal one dimensional sequences that can be generated from number theory with suitable length AB. In the past maximum length sequences have been used because they display desirable autocorrelation characteristics, but their period is 2^{m-1}, where m is an integer and so there is a limited number available. Consequently, it is necessary to examine other ways of generating optimal two dimensional arrays. This paper looks into other number theoretic sequences, and other construction techniques for forming binary arrays. The suitability of these for constructing two dimensional binary amplitude diffusers is examined. Boundary element modeling is used to evaluate their performance.

10:40

2aSP8. Coding for underwater acoustic channels. Shengli Zhou (Dept. of Elec. and Comput. Eng., Univ. of Connecticut, 371 Fairfield Rd., Storrs, CT 06269)

This talk will give an overview on channel coding, coded modulation, and their applications in underwater acoustic channels. We will cover classical block codes, convolutional codes, and the traditional coded modulation such as trellis coded modulation and bit-interleaved-coded-modulation. We will then focus on modern Turbo codes and low-density-parity-check codes, space-time coding, and highlight the recent progress on the application of the iterative (or Turbo) principle to underwater acoustic communications.

11:00

2aSP9. Pulse coding for a new scanning bistatic acoustic wind profiler. Stuart Bradley (Dept. of Phys., Univ. of Auckland, Private Bag 92019, Auckland, New Zealand, s.bradley@auckland.ac.nz) and Sabine von Hünerbein (Univ. of Salford, Salford, M5 4WT, UK)

We describe signal coding for a new design of SODAR (atmospheric acoustic RADAR) used for profiling atmospheric turbulence and winds. This bistatic SODAR uses a central vertically pointing transmitter and three synchronized phased-array scanning receivers spatially distributed on the ground and, at any instant, simultaneously pointing at the same region of the central atmospheric column. There are distinct advantages if continuous transmission can be used, since total signal power and fast profile acquisition are enhanced. However, the weak echoes mean that the receivers will record a combination of transmitted and scattered sound, so the two need to be orthogonal. This suggests a signal coding scheme. However, turbulent scattering acts similarly to an acoustic reflective diffraction grating, and this places severe constraints on signal coding. We therefore explore a sawtooth linear FMCW system, designed to optimize separation of echo and direct signal, while not detuning too much the Bragg diffraction grating relationship. An implementation of this new bistatic system and first results are discussed.

11:20

2aSP10. Time-reversed maximal-length sequences for outdoor, underwater sound propagation, and room-acoustic artificial reverberation simulations. Ning Xiang (Graduate Program in Architectural Acoust., Rensselaer Polytechnic Inst., Troy, NY 12180) and Dezhang Chu (NOAA/NMFS/NWFSC, Seattle, WA 98112)

Pseudorandom properties of maximal-length sequences (M-sequences) have long been exploited for acoustic measurements. Time-reversed M-sequence pairs also possess unique correlation properties, including a two-valued autocorrelation function and a low-valued cross-correlation function, which make them excellent candidates for acoustic measurements using simultaneous dual-sources [N. Xiang and M. R. Schroeder, J. Acoust. Soc. Am. **113**, 2754–2761 (2003)]. The application of time-reversed M-sequences was originally inspired by the outdoor acoustic tomography. This paper reports on a recent underwater experiment using the time-revered M-sequence pairs in a quasibistatic sonar system. Different from the baseband simultaneous acoustic excitations in outdoor sound propagation, the underwater application in the bistatic sonar requires ultrasonic amplitude modulation technique in order to exploit the desired correlation properties. Their excellent pseudorandom and correlation properties have also been exploited in room-acoustic applications. In addition to simultaneous dual-source room impulse response measurements, this paper also reports on creating artificial enveloping reverberations using time-reversed M-sequences.

Contributed Paper

11:40

2aSP11. Improved interference rejection in code-division multiaccess underwater acoustic communications: The near-far problem. T. C. Yang (Naval Res. Lab., 4555 Overlook Ave., Washington, DC 20375) and Wen-Bin Yang (Natl. Inst. of Standards and Tech., Gaithersburg, MD 20899)

Underwater acoustic communication is known for the signal latency due to the slow sound speed in water. This creates a severe scheduling problem for signal transmission in an underwater acoustic network involving mobile platforms or sensors, particularly when the ranges between the individual nodes are varying with time. Multiple-access communication methods such as code-division multiple-access (CDMA) that are widely used in radio frequency communications (mobile cellular network) have been considered. The problem is that the code orthogonality between the different users is destroyed by the presence of multipath arrivals in an underwater acoustic channel and severe Doppler shift in the signal. As a result, the ability to reject interference that is well known for CDMA signal is severely degraded resulting in a poor bit error rate. One approach is to recover the signal orthogonality by equalizing the multipath arrivals. However, performance of the equalization algorithm is itself degraded in the presence of interference. A different approach using the hyperspace cancellation by coordinate zeroing method is adapted in this paper for interference rejection without requiring channel equalization. Good performance is obtained using at-sea data. [This work is supported by the US Office of Naval Research.)

Meeting of the Standards Committee Plenary Group

to be held jointly with the meetings of the
ANSI-Accredited U.S. Technical Advisory Groups (TAGs) for:
ISO/TC 43, Acoustics,
ISO/TC 43/SC 1, Noise,
ISO/TC 108, Mechanical vibration, shock and condition monitoring,
ISO/TC 108/SC 2, Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures,
ISO/TC 108/SC 3, Use and calibration of vibration and shock measuring instruments,
ISO/TC 108/SC 4, Human exposure to mechanical vibration and shock,
ISO/TC 108/SC 5, Condition monitoring and diagnostics of machines,
ISO/TC 108/SC 6, Vibration and shock generating systems,
and
IEC/TC 29, Electroacoustics

P. D. Schomer, Chair,
U.S. Technical Advisory Group (TAG) for ISO/TC 43 Acoustics and ISO/TC 43/SC 1 Noise
2117 Robert Drive, Champaign, IL 61821

D. J. Evans, Chair
U.S. Technical Advisory Group (TAG) for ISO/TC 108 Mechanical vibration shock and condition monitoring, and ISO/TC 108/SC 3 Use and calibration of vibration and shock measuring devices
National Institute of Standards and Technology (NIST), 100 Bureau Drive, Stop 8220, Gaithersburg, MD 20899

A. F. Kilcullen, Co-Chair
U.S. Technical Advisory Group (TAG) for ISO/TC 108/SC 2, Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures
734 Walden Road, Hedgesville, WV 25427

R. Taddeo, Co-Chair
U.S. Technical Advisory Group (TAG) for ISO/TC 108/SC 2 Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures
1333 Isaac Hull Avenue, SE, Washington Navy Yard, Washington, DC 20376

D. D. Reynolds, Chair
U.S. Technical Advisory Group (TAG) for ISO/TC 108/SC 4 Human exposure to mechanical vibration and shock
3939 Briar Crest Court, Las Vegas, NV 89120

D. J. Vendittis, Chair
U.S. Technical Advisory Group (TAG) for ISO/TC 108/SC 5, Condition monitoring and diagnostics of machines
701 Northest Harbour Terrace, Boca Raton, FL 33431

R. Taddeo, Vice Chair
U.S. Technical Advisory Group (TAG) for ISO/TC 108/SC 5, Condition monitoring and diagnostics of machines
1333 Isaac Hull Avenue, SE, Washington Navy Yard, Washington, DC 20376

C. Peterson, Chair
U.S. Technical Advisory Group (TAG) for ISO/TC 108/SC 6 Vibration and shock generating systems
200 Dixie Ave., Kalamazoo, MI 49001

V. Nedzelnitsky, U.S. Technical Advisor (TA) for IEC/TC 29, Electroacoustics
National Institute of Standards and Technology (NIST), Sound Building Room A147, 100 Bureau Drive, Stop 8221, Gaithersburg, MD 20899–8221

The reports of the Chairs of these TAGs will not be presented at any other S Committee meeting.

The meeting of the Standards Committee Plenary Group will precede the meetings of the Accredited Standards of Committees S1, S2, S3, and S12, which are scheduled to take place in the following sequence:

ASC S12 Noise	**11 November 2008**	**11:00 a.m. to 12:45 p.m.**
ASC S1 Acoustics	**11 November 2008**	**2:15 p.m. to 3:30 p.m.**
ASC S2 Mechanical Vibration and Shock	**11 November 2008**	**3:45 p.m. to 5:00 p.m.**
ASC S3 Bioacoustics	**12 November 2008**	**9:00 a.m. to 10:30 a.m.**
ASC S3/SC 1 Animal Bioacoustics	**12 November 2008**	**10:45 a.m. to 12:00 noon**

Discussion at the Standards Committee Plenary Group meeting will consist of national items relevant to all S Committees and U.S. TAGs.

The U.S. Technical Advisory Group (TAG) Chairs for the various international Technical Committees and Subcommittees under ISO and IEC, which are parallel to S1, S2, S3, and S12 are as follows:

U.S. TAG Chair/Vice Chair	TC or SC	U.S. Parallel Committee
P. D. Schomer, Chair	**ISO/TC 43** Acoustics	S1 and S3
P. D. Schomer, Chair	**ISO/TC 43/SC1** Noise	S12
D. J. Evans, Chair	**ISO/TC 108** Mechanical vibration, shock and condition monitoring	S2
A. F. Kilcullen, Co-Chair R. Taddeo, Co-Chair	**ISO/TC 108/SC2** Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures	S2
D. J. Evans, Chair	**ISO/TC 108/SC3** Use and calibration of vibration and shock measuring instruments	S2
D. D. Reynolds, Chair	**ISO/TC 108/SC4** Human exposure to mechanical vibration and shock	S3
D. J. Vendittis, Chair R. Taddeo, Vice Chair	**ISO/TC 108/SC5** Condition monitoring and diagnostics of machines	S2
C. Peterson, Chair	**ISO/TC 108/SC6** Vibration and shock generating systems	S2
IEC		
V. Nedzelnitsky, U.S. TA	**IEC/TC 29** Electroacoustics	S1 and S3

Meeting of Accredited Standards Committee (ASC) S12 Noise

R. D. Hellweg, Chair, S12
Hellweg Acoustics, 13 Pine Tree Road, Wellesley, MA 02482

W. J. Murphy, Vice Chair, S12
NIOSH, 4676 Columbia Parkway, Mail Stop C27, Cincinnati, OH 45226

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 9:15 a.m. on Tuesday, 11 November 2008.

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.

TUESDAY AFTERNOON, 11 NOVEMBER 2008 CARISSA ROOM, 2:15 TO 3:30 P.M.

Meeting of Accredited Standards Committee (ASC) S1 Acoustics

P. Battenberg, Chair, S1
Quest Technologies, Inc., 1060 Corporate Center Drive, Oconomowoc, WI 53066-4828

R. J. Peppin, Vice Chair, S1
Scantek, Inc., 7060 #L Oakland Mills Road, Columbia, MD 21046

Accredited Standards Committee S1 on Acoustics. Working group chairs will report on the status of standards currently under development in the areas of physical acoustics, electroacoustics, sonics, ultrasonics, and underwater sound, etc. Consideration will be given to new standards that might be needed over the next few years. Open discussion of committee reports is encouraged.

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

Scope of S1: Standards, specifications, methods of measurement and test, and terminology in the field of physical acoustics, including architectural acoustics, electroacoustics, sonics and ultrasonics, and underwater sound, but excluding those aspects which pertain to biological safety, tolerance and comfort.