

Session 1aAA

Architectural Acoustics: Design, Simulation, and Perception of Architectural Acoustics

Lauren M. Ronsse, Chair

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Contributed Papers

8:00

1aAA1. Sound absorption of different green roof systems. Ilaria Pittaluga, Corrado Schenone, and Davide Borelli (DIPTM, Univ. of Genova, Via all'Opera Pia 15/A, I 16145, Genova, Italy)

Experimental data on acoustical performances, in particular on sound absorption, of several green roof systems were evaluated and discussed. Measurements were performed on samples of three green roof systems, different for maintenance, plant setting and containment criteria, and categorized in extensive green roof (sample A), semi-intensive green roof (sample B), and common soil (sample C). Experimental values of normal incidence acoustic absorption coefficient and acoustic impedance were evaluated for each sample in one-third octave frequency bands from 160 to 1600 Hz by using a standing wave tube. Then, diffusive sound absorption coefficients and normal and diffusive weighted sound absorption coefficients were calculated in the same frequency range. Results show that green roofs provide high sound absorption, mostly if compared with the typical performances of traditional flat roofs. Curves of sound absorption coefficients result strongly dependent on the stratigraphy. Comparison between the different systems performed on the base of weighted sound absorption coefficients shows a better behavior for the sample B. Results obtained suggest that green roof technology, in addition to energy and environmental benefits, can contribute to noise control in urban areas by means of high sound absorption performances in relation to the size of the surface area.

8:15

1aAA2. Acoustic properties of green walls with and without vegetation. V. Kirill Horoshenkov, Amir Khan, Hadj Benkreira (School of Eng., Univ. of Bradford, Bradford, West Yorkshire, BD7 1DP, United Kingdom), Agnès Mandon, and Rene Rohr (Canevaflor, 24, Rue du Docteur Guffon, 69170 Tarare, France)

One substantial issue with the majority of modern methods for noise control is their heavy reliance on man-made acoustic structures which require continuous service and maintenance. In this respect, the use of the inherent noise control properties of vegetation appears particularly attractive compared to other street/square treatments for reducing noise such as adding façade absorption and diffusion. A green wall with a carefully selected type of soil substrate provides an alternative to more conventional types of acoustic treatment. This work studies the influence of leaves (foliage) on acoustic absorption of soils, plants, and their combination which are typically used in green (living) walls. It is shown that the presence of plants with a particular type of leaves can result in a considerable (up to 50%) improvement in the absorption coefficient of a green wall with soil at a certain water saturation. The acoustic absorption coefficient of these systems is examined here through laboratory measurements and theoretical prediction models. The plants in this study were chosen to cover a range of possible leaf types, sizes, and densities.

8:30

1aAA3. Analysis of sound propagation in an experimental model using a high resolution scanning system. Aditya Alamuru, Ning Xiang, and Joonhee Lee (Graduate Program in Architectural Acoust., School of Architecture, Rensselaer Polytechnic Inst., Troy, NY)

The aim of this work is to analyze low frequency and mid frequency sound propagation in a coupled volume system for different aperture configurations. The cross sectional areas of the primary room and the secondary room are scanned over high spatial resolution grids using an automated scanning system. This procedure is carried out systematically for different aperture configurations. A dedicated analysis algorithm converts experimentally measured room impulse response data at each grid point into energy distributions and instantaneous sound pressure levels as a function of time. The analysis algorithm provides streams of data for a selected frequency thereby creating an animation of sound propagating through the coupled volume system. This work will demonstrate wave phenomena for different aperture configurations at low frequencies and mid frequencies by using animations to analyze the experimentally measured data.

8:45

1aAA4. Architectural acoustic elements to reduce the decay time in a room. Bonnie Schnitta, Melissa Russo, Greg Greenwald, and Michael Cain (SoundSense, LLC, 46 Newtown Ln., Ste. One, E. Hampton, NY, 11937, bonnie@soundsense.com)

The paradise architectural acoustic devices are sound modifying architectural elements, or structures. The architectural structure can be made to look like any one of the standard architectural structures commonly used in a room, from baseboards to crown moldings or ceiling beams. Depending on the intended outcome, the architectural elements can either be a solid body, or what appears to be a solid element but has internal mathematically determined channels. This allows the architectural elements, or devices, to not only reduce or correct the decay time in the room, but also make certain that the architectural elements do not produce undesirable effects. The mathematical foundation of the various shapes and designs of the architectural acoustic structures, or elements, will be presented for a linear case. This will allow a better understanding of the underlining acoustical effects. An appreciation for a more precise mathematical description of the embodiments will also be discussed by additionally taking into account the nonlinear aspects of the various embodiments. Various views of an acoustic architectural device for reducing or correcting decay time will be presented. Additionally, the improvements to the acoustic environment of the room that result from the paradise architectural elements will be provided.

1aAA5. Analyzing the auditory nature of architecture. Daniel Butko (College of Architecture, The Univ. of Oklahoma, 830 Van Vleet Oval, Norman, OK 73019, butko@ou.edu)

Architects usually place primary focus on the physical nature of materials and the aesthetic qualities of how those various materials are assembled. Although visual appeal is quite valuable when creating the built environment and specific inhabitable space(s), attention to sound is also vital in making a project successful for its intended use and daily occupants. Third year architecture students at the University of Oklahoma were tasked with a series of analytical studies and experiments that focused on the auditory nature of the built environment. This served as a precursor to the semester design project. The students spent time listening and discovering what sounds and noises were present within various functions. Each student categorized their individual findings of analyzed space into three classifications: (1) What sounds and/or frequencies they deemed successful/helpful to the intended use, (2) What sounds and/or frequencies they deemed unsuccessful/hindrance to the intended use, and (3) What additional sounds or noises they believe could have supported the intended use. The results were presented in class, discussed among the entire group, and ultimately fueled the students' future design decisions. This paper focuses on how simple analytical auditory studies can alter the overall design process to include architectural acoustics.

9:15

1aAA6. Acoustic simulation of renaissance Venetian churches. Braxton B. Boren (Music and Audio Res. Lab., New York Univ., 35 W. 4th St. New York, NY 10012, bbboren@gmail.com) and Malcolm S. Longair (Univ. of Cambridge, Cambridge, CB3 0HE, United Kingdom)

The Venetian Renaissance was a confluence of innovative expression across many artistic disciplines. While architects like Palladio and Sansovino were designing architectural masterpieces in many of the churches built during this period, composers such as Willaert, the Gabrielli, and Monteverdi were composing complex polyphonic works for split-choir ensembles, exploring the tonal and spatial dimensions of musical performance. The large churches built during this period have extremely long reverberation times and provide low clarity for understanding the complex polyphony composed for these spaces. This paper uses modern acoustic simulation techniques to provide insights into the acoustics of large Venetian churches as they would have existed during the Renaissance. In consultation with architectural historians, the authors have collected data on the structure and layout of Palladio's Redentore and San Marco on festal occasions, when large crowds, extra seating, and wall tapestries would have provided extra absorption. Using Odeon, acoustic simulations predict that under festal conditions these churches would have had significant improvements in T30, EDT, and C80. The doge's position in San Marco's chancel has particularly good clarity for sources located in Sansovino's galleries, supporting historian Laura Moretti's hypothesis that these galleries were installed for the performance of split-choir music.

9:30

1aAA7. Temporal modeling of measurement conditions to enhance room acoustical parameter characterization. Stephen Roessner (Dept. of Elec. and Comput. Eng., Edmund A. Hajim School of Eng. and Appl. Sci., Univ. of Rochester, NY 14627), Gang Ren, Mark F. Bocko, and Dave Headlam (Univ. of Rochester, NY 14627)

Forming statistical combinations of the results of repeated acoustical measurements taken under identical conditions is a common practice to reduce the effects of random noise. The most common method is to calculate the arithmetic mean of an ensemble of test results, which is based on the assumption that all experiments were conducted under identical noiseless test conditions. For most room acoustic measurement scenarios, this assumption is not valid, and non-stationary sources of noise often contaminate the results. Traditional statistical averaging methods can be improved by explicitly modeling the ambient interference and noise. Using a signal model for the noise and interference, the proposed parameter estimation procedure provides more accurate results than simple averaging in low signal to noise ratio test scenarios. This method, in which multiple, low volume measurements replace high volume test signals, provides a practical and cost-effective approach for characterizing acoustical spaces.

1aAA8. Benchmark measurements of noise, reverberation time, and an estimate of speech intelligibility in a representative operating room at Nationwide Children's Hospital in Columbus, Ohio. Richard D. Godfrey, Lawrence L. Feth (Dept. of Speech and Hearing Sci. The Ohio State Univ., 1070 Carmack Rd., Columbus, OH, godfrey.20@osu.edu), and Peter Winch (Nationwide Children's Hospital, Columbus, OH 43205)

Nationwide Children's Hospital was interested in understanding speech communications: in their operating rooms and between the parents/child and the doctor in pre-operative rooms. Long-term hearing loss of the staff was of secondary interest. Before a comprehensive project was proposed, data in a single OR to gain some experience was conducted. A SLM was programmed to measure the following during 15 s intervals: overall A-weighted equivalent energy sound level, A-weighted equivalent energy sound level in octave bands from 16 to 16 kHz, and peak un-weighted level during the interval. Reverberation was also measured by an impulsive method. Measurements were made for 23 consecutive hours. The data were downloaded for analysis. It was concluded that (1) adding some absorption around the top of the walls would improve SI, (2) good SI is only possible with a high vocal effort, and (3) long term hearing loss is very unlikely. Follow up topics before a comprehensive project is proposed were (1) try other reverberation methods, (2) study more rooms while a variety of surgical procedures are performed, (3) identify the source and duration of peaks levels, and (4) investigate other measures of SI.

10:00

1aAA9. Impacts of classroom acoustics on elementary student achievement. Lauren M. Ronsse and Lily M. Wang (Architectural Eng. Prog., Univ. of Nebraska-Lincoln, Peter Kiewit Inst., 1110 S. 67th St., Omaha, NE 68182-0861)

This research investigates relationships between unoccupied classroom acoustical conditions and elementary student achievement. Acoustical measurements were gathered in all of the third and fifth-grade school classrooms (67 total) in a public school district in north-eastern Nebraska, USA. Traditional classroom acoustic parameters, including background noise level and reverberation time, have been correlated to the standardized achievement test scores from students in the surveyed classrooms. Binaural impulse response measurements were also conducted in a subset of the rooms (20 total) and correlated to the student achievement scores. Acoustical metrics calculated from the binaural impulse response measurements include speech transmission index, distortion of frequency-smoothed magnitude, interaural cross-correlations, and interaural level differences. The results from this research indicate that scores on fifth-grade student language and reading subject areas are negatively correlated to higher unoccupied background noise levels. Also, the distortion of frequency-smoothed magnitude, which is a perception-based acoustics metric, was significantly related to the student language achievement test scores.

10:15–10:30 Break

10:30

1aAA10. A survey of residential "speaking tubes." William J. Elliot and John T. Foulkes (Cavanaugh Tocchi Assoc., Inc., 327F Boston Post Rd., Sudbury, MA 01776, welliot@cavtocchi.com)

The speech transmission index is examined for a system of "speaking tubes" within a home in the Avon Hill neighborhood in Cambridge, Massachusetts. Designed in 1888 by noted Boston architects Henry Hartwell and William C. Richardson, the Shingle Style home was both wired for electricity and outfitted with piping for gas. An electronic paging system was used to summon servants, but when aural communication was necessary, the speaking tube system was used for inter-floor communication. This paper examines the measured STI for the speaking tubes which remain in the home within the context of simple passive waveguide sound propagation. The paper also provides a quantitative evaluation of this pre-electroacoustic technology as it appeared in several fashionable homes of the late 19th and early 20th centuries.

10:45

1aAA11. Comparison of the articulation test and speech transmission index values measured in two different acoustical poor conditions. Jorge Sommerhoff (Acoust. Inst., Universidad Austral de Chile, Independencia 641, Valdivia, Chile, jsommerh@uach.cl) and Claudia Rosas (Universidad Austral, Valdivia, Chile)

In this work, a comparison is made between articulation tests and speech transmission index (STI) values, measured in the same place, in two different acoustically poor room conditions, both with STI values of less than 0.4. In the first room condition, a 200 m³ reverberation chamber with background noise of less than 32 dBA was used. In the second room condition, pink noise was added to a small room with reverberation time of less than 0.6 s, till values of STI lower than 0.4 were reached. The articulation test corpus consisted in a 1000 phonetically Spanish combination of a consonant, vowel, and consonant (CVC logatoms). The logatoms were recorded in an anechoic chamber. In the articulation test and STI measurement, both signals were emitted in the rooms using a NTI Talkbox with a sound power equivalent to a normal human voice. The STI and articulation was measured at the listener's seats which were located at different distances from the source but within STI values less than 0.4. The articulation test results of both acoustical conditions are correlated separately with the measured STI. The results of the measurements indicate that for the same STI value, the subjective response statistically differs.

11:00

1aAA12. The effect of listener head movement on perceived envelopment and apparent source width. Anthony J. Parks (Program in Architectural Acoust., School of Architecture, Rensselaer Polytechnic Inst., 110 8th St., Troy, NY 12180)

Current research examining listeners' perceived spatial impression of a concert hall relies on a fixed-head worldview, since the overwhelming majority of listening tests conducted to determine subjective spaciousness [listener envelopment (LEV) and apparent source width (ASW)] has required listeners to keep their heads fixed. Such a worldview is an incomplete one, because listeners make noticeable exploratory head movements while evaluating sonic environments, including the more common task of source localization as well as the more involved task of evaluating the spaciousness of a concert hall. This study investigates the role of listener head movement in the evaluation of perceived LEV and ASW under 15 different concert hall conditions simulated over eight loudspeakers using Virtual Microphone Control. The conditions consist of both varying ratios of front-to-back energy and varying levels of cross-correlated reverberant energy. Head movements are monitored in terms of angular rotation (azimuth, elevation, and roll) using a head tracker while listeners are prompted to give subjective ratings of LEV and ASW ranging from 1 (least) to 7 (most). The listening tests are then repeated while subjects are asked to keep their heads fixed. The head movements are analyzed and results of the tests are compared.

11:15

1aAA13. Applications of a binaural model with contralateral inhibition in room acoustics analysis. Timothy Perez, Jonas Braasch, and Ning Xiang (Grad. Prog. in Arch. Acoust., Rensselaer Polytechnic Inst., 110 8th St., Troy, NY 12180, perez2@rpi.edu)

In many cases the conventional, monophonic measures used in analyzing room acoustics show little agreement with real listeners' responses; a binaural perspective provides much-needed spatial and perceptual information that is important in acoustical quality judgments. Traditionally, binaural

models extracted information about location and intensity of sound through a relatively simple cross-correlation procedure. This paradigm was extended by Lindemann [J. Acoust. Soc. Am. **80**, 1608–1630 (1986)] with the introduction of a contralateral inhibition process, which applies a time- and intensity-dependent weighting to a pair of binaural signals and accurately reproduces results from psychoacoustical tests where the traditional model fails, such as in the case of the precedence effect. The model will be used to observe the broadening and splitting of auditory events based on the degree of interaural coherence, providing further validation of its adequacy. Then, applications in architectural acoustics will be investigated by processing binaural room impulse responses and producing a binaural activity pattern, which indicates the location and spatial extent of the resulting auditory events. These will be compared to visualizations drawn from spherical harmonic microphones. Implications of such a model on factors important in acoustical quality assessments, such as apparent source width and listener envelopment, will be discussed.

11:30

1aAA14. The audibility of direct sound as a key to measuring the clarity of speech and music. David H. Griesinger (David Griesinger Acoust., 221 Mt. Auburn St., Cambridge, MA 02138, dgriesinger@verizon.net)

Human ear/brain systems evolved to decode the direction, timbre, and distance of multiple sounds in a complex and noisy environment. In a reverberant space, this information is only available at the onset of a sound, before reflections overwhelm it. But since the time of Sabine acoustic science has concentrated on the decay of sound in a reverberant field, not on the audibility of the onset information. In addition, it is well known that the ability to separate multiple sound sources depends critically on pitch, but acoustic research studies only noise and impulses. This paper proposes that clarity requires the ability to separately analyze multiple sounds (the cocktail party effect) and that the cocktail party effect depends on phase relationships between harmonics of complex tones. These phase relationships are scrambled in predictable ways by reflections and reverberation. Well known properties of human hearing are used to develop both a physical model for the neurology of onset detection and an impulse response measure for localization and clarity in a reverberant field. A C language implementation of the physical model is capable of predicting and perhaps measuring the localizability of individual musicians in a binaural recording of live music.

11:45

1aAA15. Sound metric design based on psychological and physiological acoustics for the analysis of automotive sound. Young Joon Lee, Hong Sug Park, and Sang Kwon Lee (Dept. of Mech. Eng., Inha Univ., 253 Yonghyum Dong, In cheon 402-751, Korea)

This paper presents the correlation between psychological and physiological acoustics for the automotive sound. The research purpose of this paper is to evaluate the sound quality of interior sound of a passenger car based human sensibility. The conventional method for the objective evaluation of sound quality is to use the only sound metrics based on psychological acoustics. This method used not only psychological acoustics, but also physiological acoustics. For this work, the sounds of five premium passenger cars are used for the subjective evaluation. The correlation between this subjective rating and sound metrics based on psychological acoustics is calculated. Finally, the correlated sound metric is used for calculating the correlation between sound metric and the electron cephalogram signal measured on the brain. Throughout these results, the new evaluation system for the sound quality on interior sound of a passenger car has been developed.

Session 1aAB**Animal Bioacoustics: Acoustic Ecology**

Renata S. de Sousa Lima, Cochair

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Thomas Norris, Cochair

*Bio-Waves Inc., 517 Cornish Dr., Encinitas, CA 92024***Chair's Introduction—8:00*****Invited Papers*****8:05****1aAB1. Marine acoustic ecologies and acoustic habitats: Concepts, metrics, and realities.** Christopher W. Clark, Aaron N. Rice, Dimitri W. Ponirakis, and Peter J. Dugan (Bioacoustics Res. Prog., Cornell Univ., 159 Sapsucker Woods Rd., Ithaca, NY 14850, cwc2@cornell.edu)

Whales, dolphins, and porpoises (cetaceans) are adapted to produce and perceive sounds that collectively span 4–6 orders of magnitude along space, time, and frequency dimensions. Two important concepts, acoustic ecology and acoustic habitat, emerge from this perspective: where acoustic ecology is the study of acoustics involved in interactions of living organisms, and acoustic habitat as ecological space acoustically utilized by particular species. Cetaceans are dependent on access to their normal acoustic habitats for basic life functions. Communication masking from anthropogenic sounds that are chronically present can result in measurable losses of cetacean acoustic habitats, especially for low-frequency specialists, baleen whales. A communication masking model, informed by multi-year datasets, demonstrates cumulative influences of multiple vessels on fin, humpback and right whale acoustic habitats at spatial, temporal, and spectral scales matched to ecologically meaningful habitats. Results quantify acoustic habitat spatio-temporal variability over ecologically meaningful scales. In some habitats with high vessel traffic and vessel noise, predicted habitat loss and area over which animals can communicate is dramatically reduced compared to what it would be under non-vessel conditions. From a large-scale, ecological perspective, these acoustic habitat reductions likely represent significant costs for species for which acoustic communication is biologically critical.

8:30**1aAB2. Evaluating the potential spatial extent of chronic noise exposures of sufficient magnitude to raise concerns of wildlife impacts.** Kurt M. Fristrup (Natural Sound and Night Sky Div., Natl. Park Service, 1201 Oakridge Dr. Ste. 100, Fort Collins, CO 80525, kurt_fristrup@nps.gov)

Noise is probably the fastest growing pollutant in the United States. Traffic levels for many forms of transportation and recreation are increasing in much faster rates than population size. The consequences of chronic noise exposure for natural ecosystems are numerous and potentially severe. Decreases in pairing success, recruitment, population density, and community diversity have been documented for a variety of taxa. This presentation provide a capsule summary of documented biological impacts. These findings will be used to interpret the results from acoustical monitoring in a variety of National Park units, as well as predictions from noise models.

Contributed Papers**8:55****1aAB3. Endangered Stephen's kangaroo rats respond to road noise with footdrumming.** Debra M. Shier, Amanda J. Lea, and Megan A. Owen (San Diego Zoo Global Inst. for Conservation Res., 15600 San Pasqual Valley Rd., Escondido, CA 92027)

On-road vehicles have become a pervasive source of low frequency noise in both urban and protected areas. Because many species rely on low-frequency signals to communicate, they are likely vulnerable to signal masking and other adverse effects of road noise exposure. We recorded and quantified both road noise and low frequency footdrumming signals from endangered Stephen's kangaroo rat (*Dipodomys stephensi*; SKR), and found the two signals to overlap extensively. We then played

back footdrumming overlaid with experimental (road noise), as well as positive (crickets) and negative control (no noise) sounds to SKR. SKR showed no response to footdrumming playbacks overlaid with road noise, suggesting that noise may mask conspecific signals. Furthermore, playbacks of road noise alone provoked similar behavioral responses to those of footdrumming controls. It appears that road noise itself may mimic footdrumming and prompt a false response in SKR. Therefore, anthropogenic noise may not only mask signaling, it may also function as a deceptive signal to wildlife. For SKR, the combined effects of communication disruption and signal deception may further tax already endangered populations. Road margins serve as dispersal corridors and refugia for SKR, yet these areas may function as ecological traps if anthropogenic noise negatively affects populations.

1aAB4. Influence of impulsive sources on the soundscape of under-ice Arctic marine mammals. Juan I. Arvelo, Jr. (Nat'l. Security Technol. Dept., The Johns Hopkins Univ. Appl. Phys. Lab., 11100 Johns Hopkins Rd., Laurel, MD 20723-6099, juan.arvelo@jhuapl.edu)

The Arctic Ocean exemplifies the danger in using sound propagation and interaction models without a clear understanding of the physics of the problem or weaknesses inherent in these models. The zone-of-influence for under-ice marine mammals should be expected to differ significantly from that of open-sea organisms. However, increasing the effective sound attenuation, to empirically account for sound interactions with keel drafts, may lead to grossly erroneous conclusions from predictive and forensic studies. Ice elasticity and ridges combine to increase water/ice low-frequency sound penetration enabling long-distance transmission along this liquid–solid interface in the form of an evanescent wave. Consequently, sound pressure and exposure levels near the canopy are significantly higher even when the acoustic wavelength is several times longer than the ice thickness. Therefore, these physical mechanisms should also be taken into account in Arctic environmental impact assessment calculations. For example, it is more efficient for under-ice marine mammals to mitigate exposure to subsequent active sonar events by diving just a few meters deeper under the ice cap rather than increasing range by hundreds of meters. Therefore, some under-ice marine mammals are likely to exhibit a stronger preference toward diving avoidance behavior. [Work funded by UAF sub-award under NOAA Grant NA09NOS4000262.]

9:25

1aAB5. Seasonal presence of ringed, ribbon, and bearded seal vocalizations in the Chukchi Sea north of Barrow, Alaska. Joshua M. Jones, Ethan Roth, Bruce J. Thayre, Ian Sia (Marine Physical Lab., Scripps Inst. of Oceanogr. Univ. of California San Diego, La Jolla, CA 92093-0205), Michael Mahoney, Clarissa Zeller, Malorie Johnson, Christine Jackson, Kyle Kitka, Daniel Pickett (Mount Edgecumbe High School, AK 99835-9418), Robert Small (Alaska Dept. of Fish & Game, Juneau, Alaska), Zoe Gentes, Sean Wiggins, and John Hildebrand (Univ. of California, San Diego, La Jolla, CA 92093-0205)

Long-term autonomous acoustic recordings were collected between September and June from 2006 through 2009 in the Northeastern Chukchi Sea along the continental slope 120 km north of Barrow, Alaska. These recordings were analyzed for the presence of vocalizations of ringed seals (*Phoca hispida*), ribbon seals (*Histrophoca fasciata*), and bearded seals (*Erigonathus barbatus*). We present detailed descriptions of the acoustic repertoire of each species in addition to three-year time series of seal vocalizations and mean daily sea ice concentration. Ringed seal vocalizations are present throughout each winter and spring, indicating that they both overwinter and breed in offshore pack ice. Ribbon seal calls occur only during the open water period in 2008, but their acoustic behavior is more varied than previously described. Bearded seal vocalizations closely match well-documented calls recorded offshore near Point Barrow but have shorter duration and smaller frequency range, suggesting that demographic or behavioral differences related to breeding habitat selection may exist within the population. Bearded seal calls peak during the breeding season from March through June, but also occur in December and January annually. These long-term autonomous recordings provide details of seasonal distribution and behavior of Arctic seals that previously have not been possible to observe with other methods.

10:10–10:25 Break

Invited Papers

10:25

1aAB8. Environmental influences on acoustic communication in frogs. Peter M. Narins (Dept. of Integrative Biology and Physio., UCLA, 621 Chas. E. Young Dr. S., Los Angeles, CA 90095, pnarins@ucla.edu)

Many species of animals, including man, face the formidable task of communicating in naturally noisy environments. The effects of noise on both the calling behavior of frogs and the temporal, and spectral filtering ability of the amphibian auditory pathway are discussed. Moreover, the role of spectral, temporal, and spatial separation in minimizing background noise masking will be examined. Behavioral evidence is presented suggesting that environmental noise may act as a strong selective force in sculpting the communication

1aAB6. The acoustic ecology of minke whales in the tropical north pacific. Thomas Norris (Bio-Waves, Inc., 517 Cornish, Encinitas, CA 92024), Steven W. Martin (Space and Naval Warfare Systems Ctr. Pacific, 53560 Hull St., San Diego, CA 92152), Tina M. Yack (Bio-Waves Inc., Encinitas, CA 92024), Len Thomas (Univ. of St. Andrews, Fife KY16 9LZ, Scotland), and Julie Oswald (Bio-Waves, Inc., Encinitas, CA 92024)

The minke whale (*Balaenoptera acutorostrata*) is a ubiquitous but rarely sighted species that occurs in subtropical waters of the North Pacific during winter and spring. It produces a unique vocalization called a boing that is easy to detect and localize. We characterized the acoustic ecology of minke whales by detecting and localizing boings using passive acoustic methods. We conducted passive acoustic line-transect surveys in 2006 for a large area around the Northern Mariana Islands (site 1), and in 2010 for a smaller area off the Pacific Missile Range, Kauai, HI (site 2). We also recorded acoustic data from deep waters using cabled seafloor hydrophones at site 2. Densities of calling animals were estimated from line-transect surveys and will be used to estimate calling rates for use in spatially explicit capture–recapture analysis of fixed seafloor hydrophone data. Spatial analysis of acoustic localizations in relation to bathymetric and oceanographic variables will be discussed. We provide examples of counter-calling and complex responses to vessel noise. These results provide important information about the acoustic ecology and behavior of minke whales that can be used to improve the conservation and management of this elusive but common whale. [Work sponsored by ONR and NAVFAC.]

9:55

1aAB7. Characterizing the vocalizations of North Atlantic right whales (NARWs) in Florida, with emphasis on mother-calf pairs. Edmund Gerstein (Dept. of Psych., Charles E. Schmidt College of Sci. Florida Atlantic Univ, Boca Raton, FL 33431, gerstein2@aol.com), James Hain (Associated Scientists of Woods Hole, Woods Hole, MA 02543), James Moir (Marine Resources Council, Palm Bay, FL 32905), and Stephen McCulloch (Harbor Branch Oceanograph. Inst., Ft. Pierce, FL 34946)

The repertoire of calls, frequency of occurrence with respect to social composition, and ontogeny of vocal learning is being investigated for NARWs in their southeastern critical habitat of Florida. Small synchronized, GPS-instrumented, digital autonomous recording packages (DARPs) are deployed in the vicinity of photo-identified individuals, mother-calf pairs, and groups. The unobtrusive DARP buoys enable the recording of relatively rare, low-intensity vocal exchanges between mothers and calves. We hypothesize that it may be advantageous to be silent or to call softly to avoid predators or harassment by males in the area. These mother-calf exchanges could also be related to early developmental aspects of vocal communication. Site-specific bathymetry and active propagation measurements are conducted with vertical arrays to estimate source levels, and ranges of detection. Preliminary data indicate that exemplar (up-calls) recorded in northern habitats and used for training detection algorithms for passive auto-detection buoys are likely not appropriate for Florida waters. Social demographics, associated behavior, along with water depth and environmental parameters contribute to differences in call rates, types, source levels and respective propagation characteristics between the southeastern and northern habitats. Critical acoustic data required for selecting more appropriate calls for effective DCL algorithms in Florida waters are currently being collected.

systems of two species of Old World frogs. One torrent frog (*Odorrana tormota*) calls frequently from vegetation along fast-flowing mountain streams in Central China. These streams produce high-level, broadband noise spanning the human hearing spectrum. In addition to the high-pitched audible components, the males' calls contain prominent ultrasonic harmonics. Another frog, *Huia cavitympanum*, lives in a very similar habitat in Borneo. Unlike *O. tormota*, *Huia* can modulate its call spectrum to produce purely ultrasonic calls. It is thought that the upward shift of the call frequencies and the upper limit of sensitivity of both *O. tormota* and *H. cavitympanum* are responses to the selection pressures from their noisy habitats. [Work supported by NIDCD DC-00222, Paul S. Veneklasen Research Foundation, UCLA Academic Senate (3501).]

10:50

1aAB9. Chorussing in delphinids. V. M. Janik (School of Biology, Univ. of St. Andrews, Fife KY16 8LB, United Kingdom), P. Simard (Univ. of South Florida, St. Petersburg, FL), L. S. Sayigh (Woods Hole Oceanograph. Inst., Woods Hole, MA), D. Mann (Univ. of South Florida, St. Petersburg, FL), and A. Frankel (Marine Acoust. Inc., Arlington, VA)

The evolution of communication is strongly influenced by the social structure of animals. Here, we report how a group of offshore bottlenose dolphins in the Gulf of Mexico used chorusing of the same whistle type, while no such behavior was observed in inshore populations of the same species. We recorded 166 whistles from a group of 6 bottlenose dolphins in the Gulf of Mexico, 19 nm from the Florida coast. In an examination of the timing of whistle production, we found nine sequences in which there was considerable overlap (i.e., >50%) between whistles and another eight sequences with almost perfect overlap of the same whistle type produced by two to six animals simultaneously. Such synchrony was not expected by chance. To investigate how unique this behavior was, we also analyzed 300 h of recordings of inshore bottlenose dolphins in Florida and Scotland. In these data we found three non-significant cases of two animals showing >50% overlap. Thus, chorusing appears to be absent in inshore animals. Our data suggest that offshore bottlenose dolphins live in closed social units, which could be the result of enhanced difficulties in maintaining contact if home ranges are large.

Contributed Papers

11:15

1aAB10. Tracking dolphins using long-term autonomous acoustic recorders. Sean M. Wiggins, Martin Gassmann, Kaitlin Fraiser, and John A. Hildebrand (Scripps Inst. of Oceanogr., 9500 Gilman Dr., La Jolla, CA 92093-0205, swiggins@ucsd.edu)

Tracking marine mammals over long periods can provide information on their movement patterns including base-line behavior and responses to natural and anthropogenic stimuli. Autonomous acoustic recorders provide a cost effective and portable means of tracking these sounds over long periods, but until recently these devices have been restricted to tracking low-frequency large whales because of limited recording capabilities. In this paper, we will present long-term, passive acoustic tracking of high-frequency dolphin whistles and clicks using autonomous hydrophone recording arrays with kilometer- and meter-scale apertures.

11:30

1aAB11. High-frequency modulated signals of killer whales (*Orcinus orca*) in the North Pacific. Anne E. Simonis, Simone Baumann-Pickering (Scripps Inst. of Oceanogr., Univ. of California, San Diego, 9500 Gilman Dr. La Jolla, CA 92093-0205), Erin Oleson (NOAA Fisheries, Honolulu, HI 96814), Mariana L. Melcón, Martin Gassmann, Sean M. Wiggins, and John A. Hildebrand (Univ. of California, San Diego, La Jolla, CA 92093-0205)

Killer whales (*Orcinus orca*) use acoustic signals to echolocate and communicate, although there are differences in acoustic behavior among ecotypes. Atlantic resident populations recently have been reported to produce acoustic signals at higher frequencies than previously known. Acoustic recordings from ship-based acoustic and visual surveys and from autonomous acoustic recorders reveal that killer whales across a broad range of the North Pacific Ocean also use similar high frequency modulated signals. The median peak frequency of these signals ranged from 19.6 to 36.1 kHz at different locations, with median durations from each location ranging from 50 to 163 ms. All observed high frequency modulated signals were frequency downswept with no or few inflection points. Killer whales are generally believed to use whistles for close range communication in social contexts;

however, these uniform, repetitive, down-swept signals are similar to bat echolocation signals and may have echolocation functionality. The large geographic range of occurrence suggests that these signals are utilized by different killer whale ecotypes. [Work funded by Michael Weise at the Office of Naval Research, Frank Stone at Navy CNO-N45, Bob Haskell at Pacific Life, and Mark Spaulding at the Ocean Foundation.]

11:45

1aAB12. Long-term passive acoustic monitoring of parrotfishes (*Scaridae*) in the Hawaiian Archipelago. Lisa M. Munger (Hawaii Inst. of Marine Biology, Univ. of Hawaii, P.O. Box 1346 Kaneohe, HI 96744, lmunger@hawaii.edu), Pollyanna Fisher-Pool, Kaylyn McCoy, Marc O. Lammers, Timothy Tricas, Whitlow W. L. Au (Univ. of Hawaii, Honolulu, HI 96744), Kevin Wong, and Russell E. Brainard (NOAA Fisheries, Honolulu, Hawaii)

Parrotfishes (family *Scaridae*) are an important component of coral reef ecosystems, and this key functional group plays a major role in algae removal and bioerosion of reef substrate. They are also heavily fished in many locations, which may lead to ecosystem-wide impacts such as increased algal cover. In the State of Hawaii, parrotfish management is a priority for marine resource managers, with an ongoing need for accurate population monitoring that is currently addressed by diver-based visual surveys. However, parrotfishes are highly mobile and somewhat skittish around SCUBA divers, particularly in areas where fishing pressure is high. Because parrotfishes produce frequent audible scraping and crunching sounds associated with feeding, passive acoustic monitoring (PAM) can provide information on parrotfish occurrence without requiring the invasive presence of divers. Here, we present results from analyses of parrotfish foraging sounds in long-term acoustic recordings from 10 shallow reef locations throughout the Hawaiian Archipelago dating back to 2006. Parrotfish sounds are compared spatially across a fishing pressure gradient, from heavily fished areas in the main Hawaiian Islands to protected waters within the Papahānaumokuākea Marine National Monument (Northwestern Hawaiian Islands). Results from PAM are compared when possible with data from adjacent visual censuses conducted by divers.

Session 1aAO

Acoustical Oceanography, Underwater Acoustics, and Animal Bioacoustics: Van Holliday Memorial Session I

Whitlow W. L. Au, Cochair

Marine Mammal Research Program, Hawaii Inst. of Marine Biology, Univ. of Hawaii, Kailua, HI 96734

Kelly J. Benoit-Bird, Cochair

College of Ocean and Atmospheric Science, Oregon State Univ., 104 COAS Admin Bldg., Corvallis, OR 97331-5503

Michael J. Buckingham, Cochair

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

Timothy K. Stanton, Cochair

*Dept. of Applied Ocean Physics and Engineering, Woods Hole Oceanographic Inst., Bigelow 201, Woods Hole, MA 02543-1053***Chair's Introduction—8:15***Invited Papers***8:20****1aAO1. Dale (Van) Holliday was so much more than a scientist.** Dorian S. Houser (Natl. Marine Mammal Foundation, 2240 Shelter Island Dr. #200, San Diego, CA 92106)

Dale (Van) Holliday is well known for his acoustic studies of ocean life over a scale from plankton to mysticete whales. Van was a globally acknowledged expert valued for his participation in national and international councils governing ocean issues. Multiple times he was awarded high honors, such as the Prix d'Excellence and the Silver Medal in Acoustical Oceanography. More importantly, Van was a man of faith and no respecter of persons; he unselfishly gave of his time and knowledge and treated both students and career scientists with the level of respect due an individual. I was professionally mentored by Van and worked alongside him as a church deacon. As a deacon, I observed Van's compassion—the numerous hospital trips to visit the sick, the visitations of the home bound, and the phone calls to just “check in.” His interest in people spilled into his professional relationships, particularly with young and emerging scientists whom Van joyfully assisted and advised. I, and numerous others, have and continue to benefit from our friendship and professional relationship with Van. He was truly unique. He will be missed, but not forgotten, as his science and investment in people will remain impactful for decades to come.

8:40**1aAO2. Van Holliday: Ocean acoustician and biological oceanographer.** Richard E. Pieper (Fish Harbor Marine Lab., 820 S. Seaside Ave., Terminal Island, CA 90731)

I first met Van Holliday in 1970 at the International Symposium on Biological Sound Scattering in the Ocean. We were both graduate students, Van at Scripps and I was at the UBC. Two of us were interested in higher frequency acoustics and scattering from zooplankton. In the Working Group on Bioacoustics Recommendations, Brooke Farquhar and Van Holliday wrote “By using acoustic techniques over large frequency ranges (100 Hz to 10 MHz), the distribution of nekton and plankton could be obtained.” I moved to USC after graduation and began to meet Van at ONR site reviews. We received funding from ONR and NSF in mid 1970. I bought a plankton pump and Van put together a four-frequency acoustic array (0.5, 1.16, 1.80, and 3.08 MHz). The program began and continued for over 30 yr. With the success of our four-frequency system, we obtained a recently de-classified Shadowgraph system from the Navy and Van built a 21-frequency array (100 kHz to 10 MHz) which was used in many ocean environments. The uniqueness of scattering from zooplankton led Van to develop an inversion algorithm to calculate zooplankton size spectra from the acoustic data. The four-frequency TAPS was designed and is used by many today.

9:00**1aAO3. Van Holliday: A lifetime of contributions to acoustical oceanography.** David M. Farmer (The Graduate School of Oceanogr., Univ. of Rhode Island, 215 South Ferry Rd., Narragansett, RI 02882)

Van Holliday's achievements have transformed the acoustical study of marine biology. Working closely with colleagues from fisheries and marine biology, he brought his keen understanding of acoustics and lively curiosity to the solution of many challenging

problems. In reviewing his accomplishments one is struck by their range and by the special way in which he reached out to the fields to which he contributed. For example, when he solved a problem such as acoustical scattering by fish schools, he quickly saw the possibilities of exploiting his new understanding to study schooling behavior. He explored the characteristics of ice noise, he was the first to track the movement of whales acoustically and he made major contributions to our understanding of the scattering of sound by zooplankton. His work on plankton acoustics led to the important new sub-discipline of spectral acoustic determination of zooplankton populations and their behavior. His profound contributions to biology, biophysics, and other marine topics display an intellectual breadth, an enthusiasm for crossing disciplinary boundaries, and a deep curiosity that serve us well as a model for achievement in the field of acoustical oceanography.

Contributed Papers

9:20

1aAO4. On Van Holliday's shoulders. Orest Diachok (Johns Hopkins Univ. Appl. Phys. Lab., Laurel, MD 20723-6099)

The year was 1992. The Cold War was over, and funding for resolving deep water issues was fading. I was at the NATO Undersea Research Centre, simultaneously searching for a new research challenge that I could sink my teeth into, and formulating a research program for the Centre, which would be appropriate for the post-Cold War era. I stumbled onto Van's classic paper on resonance scattering by fish, discussed it with him by telephone, and within an hour became a convert to marine bioacoustics. I became familiar with David Weston's work, discussed it with him, and soon thereafter started my research in bioacoustics. Van and David made important contributions to the design of my bioacoustics experiments. After I returned to the USA, I often met with Van to discuss a broad spectrum of fundamental and applied topics in bioacoustics. He was always generous with his time, knowledge, and insights. His explanations of seemingly complex phenomena were always readily understandable, concise, and precise. Standing on Van Holliday's shoulders, greatly expanded my vision of what is possible through technical innovation, interdisciplinary collaboration, dedication, and perseverance. I, along with many others, miss and will continue to miss this amazing and unique individual.

9:35

1aAO5. Acoustics as a tool to answer fundamental marine ecological questions: Thanks Van! James E. Eckman (California Sea Grant Prog., Scripps Inst. of Oceanogr., Univ. of California San Diego, 9500 Gilman Dr. 0232, La Jolla, CA 92093, jeckman@ucsd.edu)

Van Holliday was an acoustician with a sound appreciation (apologies) of the complexity, importance, and beauty of marine animals and plants. His bio-acoustical work, motivated initially by an interest in the significant impacts of fish on acoustic backscatter, rapidly led to studies that addressed the value of that backscatter in answering scientific questions about fish. His research and interests expanded rapidly to provide us with new tools capable of detecting and mapping zooplankton. Moreover, his later efforts contributed to an appreciation of the dynamics and importance of the productivity of benthic microalgae in shallow sediments. While many appreciate the value of his contributions to acoustics, and to the basic detection and mapping of planktonic and nektonic life forms, fewer scientists appreciate that the tools (hardware and software) he developed have helped open a door that enables us to address fundamental biological and ecological questions regarding plankton dynamics and benthic-pelagic couplings: questions that still remain inadequately explored. From my perspective as a former program manager at ONR, I will discuss some of Van's contributions that provide a gateway to asking, and answering, a wide-range of ecologically important questions.

9:50

1aAO6. Broadband active acoustic sensing of fish and zooplankton in the kilohertz to megahertz range: Pursuing Van Holliday's vision. Timothy K. Stanton (Dept. Appl. Ocean Phys. and Eng., Woods Hole Oceanograph. Inst., Woods Hole, MA 02543-1053, tstanton@whoi.edu), Dezhang Chu (NOAA Natl. Marine Fisheries Service, Seattle, WA 98112), and Andone C. Lavery (Woods Hole Oceanograph. Inst., Woods Hole, MA 02543-1053)

Van Holliday had a vision for sensing marine organisms with active acoustics over a very wide range of frequencies. This inspired us at the

Woods Hole Oceanographic Institution, Woods Hole, MA, to conduct a series of measurements, both in the laboratory and in the ocean, and associated modeling, over the range of 1.5 kHz to 3 MHz over the past 23 years. The organisms were as small as millimeter-size copepods and as large as 20-cm herring and squid. Broadband acoustic scattering measurements were conducted in the laboratory as a function of frequency (24 kHz to 3 MHz) and angle of orientation (0–360 deg) of many species. Instruments were developed to measure broadband acoustic scattering in the ocean over the range 1.5 kHz to 1.2 MHz with some gaps. Scattering models, based on the laboratory data, were also developed for several major anatomical groups of organisms and spanned a range of complexity, from low-resolution models that account only for length, width, and general shape to high resolution models that account for shape of the body and heterogeneities within the body in three dimensional at fine scale as well as including roughness. In this presentation, we review the laboratory measurements and scattering models, as well as development of the broadband ocean instruments and their use at sea.

10:05–10:20 Break

10:20

1aAO7. Planktonic layers: New insights stimulated by Van Holliday. Timothy J. Cowles (Consortium for Ocean Leadership, 1201 New York Ave. NW, Washington, DC 20005, tcowles@oceanleadership.org) and Kelly Benoit-Bird (Oregon State Univ., Corvallis OR 97331, kbenoit@coas.oregonstate.edu)

During the late 1980s and early 1990s, initial evidence for persistent thin layers of phytoplankton (less than 1 m in thickness) in the upper ocean was obtained with optical instrumentation. These observations were inconsistent with the existing understanding of small-scale vertical mixing processes and raised questions about the ecological consequences of such structures, should they prove to occur on a regular basis. Dr. D. Van Holliday quickly saw the need for new approaches in acoustical oceanography to address these important ecological questions. Over a period of a few years, Dr. Holliday developed new acoustical tools that could be deployed in concert with other sensors. His moorings with customized high-frequency transducers allowed acoustical resolution over scales of centimeters, sufficient to capture the acoustic signature of marine zooplankton and their spatial relationship to their food supply. The insights provided by Van's work, and his constant encouragement to his colleagues, have led to significant breakthroughs in our understanding of upper ocean physical, biological and chemical processes. This presentation will incorporate recent observations and build upon Van's observations to illustrate the importance of his contributions to ocean science.

10:35

1aAO8. Parsing the prose of D. V. Holliday. Kenneth G. Foote (Woods Hole Oceanograph. Inst., Woods Hole, MA 02543)

The published works of D. V. Holliday have been praised as exemplifying the scientific method [K. G. Foote, *J. Acoust. Soc. Am.* **115**, 2521 (2004)]. They also exemplify a direct writing style that embodies some elements of a physical theory. Paraphrasing P. Duhem in *The Aim and Structure of Physical Theory* (Princeton University, 1954), these works, by Holliday, communicate "as simply, as completely, and as exactly as possible, a whole group of experimental" findings. These stylistic features are

illustrated by reference to three papers published in JASA under Holliday's name, one with a coauthor, during the period 1972–1980.

10:50

1aAO9. Active acoustic examination of the diving behavior of murrens foraging on patchy prey. Kelly J. Benoit-Bird (College of Oceanic and Atmospheric Sci., Oregon State Univ., 104 COAS Admin Bldg., Corvallis, OR 97331, kbenoit@coas.oregonstate.edu)

Van Holliday used sound to study nearly every type of organism living in the ocean, contributing to our understanding of acoustics as well as marine ecological processes. To honor Van, I will talk about the one animal group that I could not find in his long publication list—seabirds. We combined visual observations of murrens with active acoustics, fish trawls, zooplankton net tows, and hydrographic measurements in the area surrounding breeding colonies in the southeastern Bering Sea. We detected thousands of unique acoustic targets that were strongly correlated with the number of visually detected murrens, providing a new tool for quantitatively studying the foraging ecology of diving birds. Diving murre abundance was related to the combined availability and vertical accessibility of squid, krill, and pollock. Individual krill patches targeted by murrens had higher krill density and were shallower than mean values but were similar in total krill abundance and overall size. Murrens found outside of krill showed a depth distribution similar to that of juvenile pollock. The high proportion of diving murrens in aggregations and their consistent inter-individual spacing support the hypothesis that intra-specific local enhancement may facilitate foraging in these predators.

11:05

1aAO10. Zooplanktivory of fishes measured with a dual wide band sonar/optical imaging system. Amatzia Genin (Hebrew Univ. and Interuniversity Inst. Mar. Sci. Eilat 88203, Israel), Jules Jaffe (Scripps Inst. of Oceanogr., La Jolla, CA 92093-0238), Yoav Lindemann (Hebrew Univ. and Interuniversity Inst. Mar. Sci. Eilat 88203, Israel), Paul Roberts (Scripps Inst. of Oceanogr., La Jolla, CA 92093-0238), and Yonathan Gutel (Hebrew Univ. and Interuniversity Inst. Mar. Sci. Eilat 88203, Israel)

Recent experiments in several near shore habitats in Eilat, Israel, were performed to measure various aspects of predation on zooplankton. Toward this goal, two sets of (4) wide band echo-sounders that can identify echoes from individual sub-millimeter copepods in liter-sized volumes were deployed. The echo sounders were augmented with an underwater optical shadowgraph imaging system that concurrently imaged a 100 ml volume with 25 μm resolution that provided many usable *in-situ* images of the animals that were producing the acoustic reflections. Sonars were located both upstream and downstream from a group of zooplanktivorous fish, allowing measurement of zooplankton abundance in water parcels before and after they passed through the fish group. Information on fish abundance and movements was obtained with concurrent video records. Together with ancillary environmental measurements of flow rate and light level, zooplanktivory rates of: animals consumed per cubic meter per fish were computed from the differential concentration of animals as inferred from the two sets of four echo-sounders. The results permit the estimate of important environmental features of the ecosystem such as the dependence of predation rate on prey abundance, their size, and flow speed.

1a MON. AM

11:20–11:40 Panel Discussion

MONDAY MORNING, 31 OCTOBER 2011

SUNSET, 8:15 TO 11:25 A.M.

Session 1aSA

Structural Acoustics and Vibration: Multifunctional Composite Structures

Gopal P. Mathur, Cochair

The Boeing Company, 5301 Bolsa Ave., Huntington Beach, CA 92647

Noureddine Atalla, Cochair

Dept. of Mechanical Engineering, Univ. de Sherbrooke, Sherbrooke QC J1K 2R1, Canada

Chair's Introduction—8:15

Invited Papers

8:20

1aSA1. Multifunctional composite materials and structures: A brief review. Ronald F. Gibson (Dept. of Mech. Eng., MS-312, Univ. of Nevada-Reno, Reno, NV 89557)

Recent advances in the area of multifunctional materials and structures are reviewed. Interest in this area has been driven by the need for systems that simultaneously perform structural and nonstructural functions. Multifunctional materials are by nature composite materials and new nanoreinforcements, in particular, have made it possible to achieve simultaneous improvements in properties such as stiffness, compression strength, damping, electrical conductivity, and fracture toughness. For example, among the most important nonstructural functions that a structure may need is electrical conductivity, but many composites have poorly conducting polymer matrix materials. However, very small concentrations of carbon nanotubes or other conducting nanoreinforcements in polymers lead to disproportionately large improvements in the electrical conductivity of the nanocomposite. Recently developed composites with piezoelectric structural fiber reinforcements are capable of vibration control, damping, energy harvesting/storage, or structural health monitoring. Recent research has also demonstrated the feasibility of self-healing polymers and polymer composites based on the use of a microencapsulated healing agent and a catalyst for polymerizing the healing agent. Structurally integrated electronics such as batteries for energy storage are another recent application of multifunctional structure design. Other important nonstructural functions in multifunctional composite structures include electromagnetic interference shielding, optical transparency, and thermal conductivity.

8:40

1aSA2. Multifunctional acoustic metamaterial composites. Christina J Naify and Steven Nutt (Dept. of Mater. Sci., Univ. of Southern California, 3651 Watt Way VHE 402, Los Angeles, CA 90089)

Composite structures used in aerospace applications are designed to optimize high bending stiffness to weight ratio. Acoustical performance of composite structures, however, is notoriously poor due to decreased mass law performance and decreased coincidence frequency. Efforts to improve the acoustic properties of composite structures have included optimization of material selection as well as addition of acoustic treatments. Additionally, development of composite structures to include multifunctional properties has increased. In this study, two types of multifunctional approaches were examined using acoustic metamaterials. Locally resonant acoustic metamaterials (LRAM), which have sound insulation performance of 500% increase over the mass law prediction, were integrated into a high-strength sandwich structure array to provide increased acoustic performance without increase in mass. LRAM were constructed of thin, tensioned membranes with centrally located masses in the form of small magnets. Varying the geometry of the metamaterial to tune effective frequencies optimized acoustic performance. Acoustic excitation of the central magnet was used to harvest energy by positioning a wire coil around each cell such that the displacement of the magnet induced a voltage. Combination of energy harvesting and array configurations produced multifunctional materials with three applications: increased stiffness, optimal acoustic performance, and harvesting of acoustic energy.

9:00

1aSA3. Wave number and damping characterization for sound and vibration mitigation in sandwich composite structures. James J. Sargianis and Jonghwan Suhr (Dept. of Mech. Eng., Univ. of Delaware, 130 Acad. St., Newark, DE 19716, James.Sargianis@gmail.com)

With the rising demand for high performance composite materials, there is a great interest for multi-functional materials. Our research focuses on materials with high noise mitigation and passive structural damping with minimal sacrifice in bending stiffness. Specifically, we seek to understand the vibrational properties of carbon-fiber face sheet sandwich beams, with interest in wave number and damping characteristics. Both experimental and analytical methods were applied to characterize the wave number response of sandwich beams, from which coincidence frequencies were obtained. From the same frequency response function, structural damping ratios were calculated using the half-power bandwidth method. Results showed that for low frequency applications, decreasing bending stiffness has the greatest effect on increasing the coincidence frequency. However for higher frequency applications, an improvement in coincidence frequency can be seen if one reduces the core's shear modulus. Moreover it may be concluded that the high amplitudes seen in the wave number domain may be contributed to the lower structural damping values at low frequencies. With both wave number and damping properties being frequency dependent, one can optimize design parameters pertaining to a certain frequency range which will improve damping and acoustic properties while maintaining necessary flexural stiffness.

9:20

1aSA4. Overview of cumulative results of characterization studies of composites. Bernhard R. Tittmann (Dept. Eng. Sci. & Mech., Penn State, University Park, 212 EES, PA 16802)

After an introduction into design concepts of composites, this paper presents a survey of material characterization investigations of a variety of composites ranging from graphite/epoxy, to metal-matrix, to carbon/carbon to CF/PEEK, and to biological material such as plant cell walls. Discussed are the results of a series of studies in anecdotal form, which include the characterization of soft-body impacts with gelatin projectiles as simulation due to bird strike, the healing of impact damage as imaged and followed by increasing temperature (5000 °C) in acoustic microscopy, finite element simulations of embedded piezoelectric element transducers, acoustic shear velocity measurements during the curing of graphite/epoxy; acoustic emissions during carbonization of carbon/carbon by the use of guided wave techniques inside an autoclave; and acoustic microscopy imaging in the characterization of metal-matrix composites. Always a factor is the resolution requirement. At the extreme end of the resolution capability of current instrumentation is the sub-nanometer resolution of the atomic force microscope which has been demonstrated by the imaging of plant cell walls (onion skin), which are a form of nature's composite structure. These topics have given insight into the many facets of problems as well as opportunities for the use of the characterization of composites.

9:40

1aSA5. Transmission loss of curved sandwich-composite panels with attached noise control materials. Nouredine Atalla (Dept. of Mech. Eng., Univ. de Sherbrooke, Sherbrooke (QC), J1K 2R1, Canada) and Franck Sgard (Inst. de recherche Robert-Sauvé en santé et en sécurité du travail, Montréal (QC), H3A 3C2, Canada)

This paper discusses the modeling of the transmission loss of curved sandwich-composite panels with attached noise control treatments using both analytical and numerical methods. Special attention is devoted to the modeling using the Transfer Matrix Method (TMM) and Statistical Energy Analysis (SEA) of these structures in various mounting conditions (single wall and double wall) under diffuse acoustic field excitation with a systematic comparison with an efficient FEM/VBEM formulation of the problem. Classically, in SEA models the sound package is unwrapped and the TMM is used to calculate its effects in terms of added damping, absorption, and insertion loss. Examples are presented to examine the validity of this practice and demonstrate its range of applicability and usefulness.

10:00–10:15 Break

10:15

1aSA6. Active control of a composite panel utilizing piezoelectric patches connected to negative capacitance shunts. Kenneth A. Cunefare, Benjamin S. Beck (The Georgia Inst. of Technol., School of Mech. Eng., Atlanta, GA 30332, ken.cunefare@me.gatech.edu), and Francisco Mariano Bada Romero (Madrid Polytechnical Univ., INSIA, Carretera de Valencia, 28031 Madrid)

Many industries are implementing the use of thin, lightweight carbon fiber panels to increase stiffness and decrease weight. Yet, vibrations of the panels can reach large amplitudes causing an increased acoustic noise field. The use of piezoelectric actuators bonded on or within the

composite panels can be used to decrease the vibration. Negative capacitance shunts have been shown to decrease flexural vibrations over a broadband frequency range. By using the negative capacitance shunts connected to piezoelectric patches, the noise field can be reduced. Yet, the effect of the control may also cause increased acoustic coupling causing more of the flexural modes to create propagating acoustic waves. The acoustic effects of the control system on a clamped carbon fiber composite panel are analyzed by investigating the flexural amplitude and wave number decomposition. The results of the numerical model of the panel are experimentally validated.

10:35

1aSA7. Resonant frequencies of rectangular plates immersed in fluids. Kai Ming Li (Dept. of Mech. Eng., Purdue Univ., 140 S. Martin Jischke Dr., West Lafayette, IN 47907-2031)

The response of a fluid-loaded structure is a subject of considerable interests in many areas of engineering. This includes applications in aerospace industry for composite structures, design of offshore and building structures partially immersed in water, and the design of rectangular micro-plates for bio-sensing devices. For many decades, it has been well recognized that the resonant frequencies of structures in contact with fluid decrease significantly if the fluid-loading on the structure is very heavy. For somewhat lighter fluid-loading, the structural properties are important, and the in vacuo resonant frequencies are usually needed in determining the response due to an external driving force. This paper exploits a simple empirical model to estimate the effect of fluid-loading on the resonant frequency of a rectangular plate. Simple formulas were developed to rapidly compute the natural frequencies of rectangular plates loaded with different fluids on both sides. The rectangular plates with simply supported or clamped edges were considered in the present analysis. Particularly, a square plate with a general boundary condition varying from simply supported to clamped edges was examined. Empirical formulas were derived to calculate the change in the resonant frequencies for baffled plates in all cases.

Contributed Papers

10:55

1aSA8. Acoustic radiation from finite bilaminar submerged plates: Three-dimensional elasticity solution. Sabih I. Hayek (Dept. of Eng. Sci. and Mech., Penn State Univ., University Park, PA 16802) and Jeffrey E. Boisvert (NAVSEA Div. Newport, Newport, RI 02841)

The vibration and radiation of a submerged baffled finite rectangular bilaminar plate is obtained analytically using the three-dimensional equations of elasticity. The plate is composed of two perfectly bonded finite layers of identical size. The boundary conditions on the perimeter of the plate are free of shear stresses and pinned on the in-plane displacements. The plate is coupled to acoustic media on both sides and is baffled by an infinite rigid plane. The solution for the vibration response due to normal surface forces is found in terms of the bilaminar plate eigenmodes. The vibratory response and the associated near- and far-field radiated acoustic pressures are computed for various ratios of thickness to plate dimensions over a broad frequency range. [Work supported by the ASEE Summer Faculty Research Program.]

11:10

1aSA9. Vibrational characteristics of wood, aluminum, and composite hockey sticks. Linda J. Hunt (Dept. of Phys., Kettering Univ., 1700 W. University Ave., Flint, MI 48504) and Daniel A. Russell (Penn State Univ., University Park, PA 16802)

The stick used by ice hockey players consists of a long straight shaft attached to a curved blade. Composite materials have replaced wood and aluminum shafts for the vast majority of current professional and amateur players. The stiffness of the shaft plays a crucial role in the amount of potential energy that can be stored and released during a slap shot. Shafts are available in a wide range of stiffness and flex ratings in order to match player preference. Several wood, aluminum, and composite shafts were tested using a roving hammer experimental modal analysis with and without their blades. Mode shapes of the shaft tested alone were found to be those of a free-free beam. For shafts of similar lengths, aluminum shafts had the highest resonance frequencies and the lowest damping coefficients, while wood shafts had the lowest frequencies and the highest damping. Vibrational characteristics of whole sticks, including one-piece, two-piece sticks (shaft and blade from same material), and hybrid (shaft and blade of different materials) show that the presence of the blade significantly lowers the frequencies of the torsional modes of vibration. These results, especially damping coefficients, suggest reasons for the anecdotally preferred "feel" provided by composite sticks.

Session 1aSP

Signal Processing in Acoustics, Noise, Underwater Acoustics, Acoustical Oceanography, and Animal Bioacoustics: Sampling Methods for Model-Based Parameter Estimation

Ning Xiang, Cochair

Dept. of Architecture, Rensselaer Polytechnic Inst., 110 8th St., Troy, NY 12180

Paul M. Goggans, Cochair

*Electrical Engineering Dept., Univ. of Mississippi, University, MS 38677***Chair's Introduction—8:00*****Invited Papers*****8:05****1aSP1. Using the Markov chain Monte Carlo method to estimate model order.** Paul M. Goggans and Chung-Yong Chan (Dept. of Elec. Engr., Univ. of Mississippi, Anderson Hall Rm. 302B, University, MS 38677, goggans@olemiss.edu)

Markov chain Monte Carlo (MCMC) methods are widely used in the solution of parameter estimation problems arising in acoustics and other applications. The use of MCMC to estimate the parameters of a single model is well established. However, in many applications, there is not a single model for the data but rather a number of competing models. A common method of dealing with multiple models is to use MCMC to compute the posterior probability and estimate the parameter values of each model in turn. However, for problems with many models, it is more efficient to combine the parameter spaces of all models into a single space and use MCMC to perform across-model sampling of the joint space. Although the development of an MCMC algorithm of this sort is sufficiently difficult so as to be unprofitable for the non-specialist, the acoustician wishing to solve their multi model parameter estimation problem using MCMC can still do so using an existing algorithm. This presentation gives an overview and brief tutorial of MCMC for parameter estimation and then discusses and gives an example of using the open source computer program BayeSys [Skilling, 2004] to determine the model order of a simple atomic model.

8:25**1aSP2. Bayesian inversion of seabed reverberation and scattering data via parallel tempering.** Stan E. Dosso (School of Earth and Ocean Sci., Univ. of Victoria, Victoria BC, Canada, V8W 3P6) and Charles W. Holland (The Penn. State Univ., State College, PA 16804-0030)

This paper describes Bayesian inversion of reverberation data for seabed scattering and geoacoustic parameters using the method of parallel tempering. The seabed is modeled as a sediment layer over a semi-infinite basement, with interface scattering occurring at the rough upper and lower boundaries of the sediment and volume scattering within the layer. The scattering mechanisms are considered to be independent and are modeled using perturbation theory and the Born approximation. Unknown parameters include seabed geoacoustic properties (sediment thickness and sound speeds, densities, and attenuations for the sediment and basement) and scattering properties (roughnesses and scattering strengths for upper and lower layer boundaries and volume scattering strength for the sediments). The reverberation inversion problem is found to be strongly nonlinear with a highly multi-modal posterior probability density (PPD). Standard Markov-chain Monte Carlo (MCMC) methods, such as Metropolis–Hastings sampling, are ineffective at sampling the complicated parameter space. However, parallel tempering, which runs multiple MCMC chains at a series of increasing temperatures with probabilistic transitions between chains, effectively samples the multi-modal PPD. Methods to increase efficiency using multiple parallel chains at each temperature and exploiting improved mixing with temperature are considered.

8:45**1aSP3. Trans-dimensional strategies for geoacoustic posterior probability estimation.** Jan Dettmer and Stan E. Dosso (School of Earth and Ocean Sci., Univ. of Victoria, Victoria BC, Canada V8W 3P6)

Choosing appropriate model parametrizations is a fundamental aspect of Bayesian parameter inference. Trans-dimensional inference is based on a hierarchical Bayesian model, where the number of unknowns in the problem is itself unknown. The methodology extends the state-space to the union of subspaces of a group of models of interest. This allows the data to estimate the support for the parametrizations under consideration while accounting for the limited knowledge about the parametrization in the posterior probability density estimate. Algorithms, such as reversible-jump Markov chain Monte Carlo, can be used to sample from the trans-dimensional posterior by proposing and accepting/rejecting dimensional transitions (jumps) according to a generalized Metropolis-Hastings criterion. Several challenges exist for the efficient application of trans-dimensional methods to geoacoustic inference including defining proposal distributions for efficient transitions between dimensions and within dimensions, and specifying (or quantifying) data errors distributions (or statistics). Example 1109; of applying the trans-dimensional approach are demonstrated for several geoacoustic inverse problems, using trans-dimensional partition modeling and hierarchical data-error models.

9:05

1aSP4. Estimation of the conditional variance of a broadband source signal employing a repetition code through shallow water waveguides. Michael Pfetsch and Paul Gendron (Maritime Systems Div. SSC-Pacific, 53560 Hull St., San Diego, CA 92152)

A repetition code can be employed as a computationally fast suboptimal means to exploit available time-bandwidth product for improved bit error rate performance. Applications include synthetic aperture communications. Underwater acoustic response functions can vary over the duration of the transmission and thereby degrade system performance. A measure of precision of estimation of the source signal is the source posterior variance given the receiver pressure field time series. Presented here is the computation of the covariance of a source signal accounting for the covariance of the acoustic response function. A Gibbs sampling scheme is employed as a computational method to computing these variances to an acceptable precision. The resulting posterior variance as a function of SNR gives insight into the contributing phenomena that impart ambiguity in synthetic aperture communications through underwater acoustic channels. The method is tested on the very shallow water environment of Keyport WA at a center frequency of 20 kHz.

9:25

1aSP5. Comparison of particle filtering and extended Kalman filtering for acoustic-based tracking of low-flying aircraft. Wm. Garth Frazier (Natl. Ctr. for Physical Acoust., Univ. of Mississippi, 1 Coliseum Dr., University, MS 38677, frazier@olemiss.edu) and Chad Williams (Hyperion Technol. Group, Tupelo, MS 38804)

This presentation summarizes a comparative study of particle filtering and extended Kalman filtering applied to acoustic-based tracking of high-speed, low-flying aircraft. A distributed network of small acoustic arrays, each reporting real-time azimuthal bearings and elevation angles to acoustic sources to a central processing unit, are synthesized into real-time three-dimensional tracks. The primary challenge of the problem is the significant propagation delay between the source and the receivers. Both tracking methods are applied to simulated and field test data and reveal nearly equivalent tracking performance in all cases as long as a sufficient number of particles are utilized. Computational requirements of the extended Kalman filter are significantly less than the particle filters.

9:45

1aSP6. Sequential Bayesian filtering for a varying model-order passive fathometer problem. Caglar Yardim (Marine Physical Lab., Univ. of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093, cyardim@ucsd.edu), Zoi-Heleni Michalopoulou (New Jersey Inst. of Technol., Newark, NJ 07102), and Peter Gerstoft (Univ. of California, San Diego, CA 92093)

Sequential model selection is demonstrated for a drifting passive fathometer case. It has been shown that, by processing noise data at a specific array location, a reflector sequence can be extracted, consisting of a summation of sinc pulses. The center of each pulse identifies the depth of a reflector in the ocean environment at that location. Extracting the number and peak/depth locations of these pulses in the reflector sequence provides insight in the sediment structure of the medium. Collecting data in multiple ranges, a process facilitated by the drifting array, allows the study of multiple reflector sequences. Similarly to spatial time delay tracking with Bayesian filters that sample from posterior density functions, we treat sequences obtained at different ranges as data arriving sequentially into a particle filter that extracts at every range (state) the number of pulses and their corresponding depths using an observation equation. A state equation then predicts reflectors at the next range and updates estimates accordingly. The number of pulses varies with range, following changes in sediment layering. Probability density functions of the number of layers and their depths are calculated and demonstrate the successful tracking of changes in the structure of the ocean environment and the uncertainty therein.

10:05–10:30 Break

10:30

1aSP7. Passive sonar tracking using sequences of received signal amplitude fluctuations: Dependence on environmental sampling. R. Lee Culver, Brett E. Bissinger, and Alex W. Sell (Appl. Res. Lab, Penn State Univ., P.O. Box 30, State College, PA 16804)

We have developed a passive sonar tracking algorithm that makes use of variations in the amplitude of the signal received from a source in motion. Originally the likelihood function (probability density function (pdf) of received signal amplitude for a given source location) was calculated by Monte Carlo sampling of the environmental variables and running the acoustic propagation model to predict transmission loss (TL). For each possible source location, the pdf of TL was constructed. To calculate the posterior pdf using received signal amplitude data, Bayes' rule was used sequentially such that for each possible source location, the likelihood function evaluated at the value of the new received amplitude was multiplied by the prior probability associated with that source location. This approach depends fundamentally on how the environment is sampled and on the acoustic propagation model. More recently, the likelihood function has been expanded into the joint pdf of sequences of received signal amplitudes. The environment sampling and use of the acoustic propagation model are the same, but now the likelihood functions are multidimensional. Implications for environmental sampling and selecting the proper model order are discussed. Work supported by the Office of Naval Research Undersea Signal Processing.

10:50

1aSP8. Sequential Bayesian filtering for seismic tremor location. Caglar Yardim, Peter Gerstoft, William S. Hodgkiss (Scripps Inst. of Oceanogr., Univ. of California, San Diego, La Jolla, CA 92093, gerstoft@ucsd.edu), and Eliza Michalopoulou (Univ. Heights, Newark, NJ 07102-1982)

Sequential filtering provides a suitable framework for estimating and updating the unknown parameters of a system as data become available. The foundations of sequential Bayesian filtering with emphasis on practical issues are first reviewed focusing on particle filtering and particle smoothing. Filtering is demonstrated to be a powerful estimation tool, employing prediction from previous estimates and updates stemming from physical and statistical models that relate seismic measurements to the unknown parameters. Particle filtering and particle smoothing are discussed for tracking multiple tremor locations.

11:10

1aSP9. Importance-based sampling for porous material physical parameter estimation. Cameron Fackler and Ning Xiang (Graduate Program in Architectural Acoust., School of Architecture, Rensselaer Polytechnic Inst., 110 8th St., Troy, NY 12180, facklc@rpi.edu)

Bayesian inference is applied to the problem of determining the physical parameters of a rigid-frame porous material. Such materials may be characterized by the parameters of flow resistivity, porosity, and tortuosity. The Biot-Allard and Attenborough models predict the propagation of sound in rigid-frame porous materials by modeling the characteristic impedance and propagation coefficient of the material in terms of these physical parameters

and a shape factor. In this work, model-based Bayesian analysis is formulated to estimate the values of these parameters from experimental measurements of the characteristic acoustic impedance or propagation coefficient of a material under test. Importance sampling and related methods are used in the parameter estimation procedure as Monte Carlo approaches to characterize the posterior probability distribution which is used to represent the likelihood of parameter values. To increase the efficiency of the sampling, adaptive strategies are employed to extend the classical importance sampling. This analysis provides quantitative estimates of the parameter values as well as estimates of the uncertainty associated with each parameter and the interrelationship between parameters.

MONDAY MORNING, 31 OCTOBER 2011

PACIFIC SALON 3, 8:00 TO 11:45 A.M.

Session 1aUW

Underwater Acoustics and Structural Acoustics and Vibration: Finite Element Modeling of Acoustic Scattering from Objects in a Heterogeneous Medium

Ahmad Abawi, Cochair

Heat Light and Sound Research, Inc., 3366 Torrey Pines Ct., La Jolla, CA 92037

David S. Burnett, Cochair

Naval Surface Warfare Center, 110 Vernon Ave., Panama City, FL 32407

Invited Papers

8:00

1aUW1. Azimuthal Fourier mode decomposition of generic incident fields in the frequency domain: Computational model and results. Mario Zampolli (TNO, Sonar Group, Oude Waalsdorperweg 63, 2597 AK The Hague, The Netherlands, mario.zampolli@tno.nl), Aubrey L. Espana, Kevin L. Williams (Univ. of Washington, Seattle, WA 98105), and Philip L. Marston (Washington State Univ., Pullman, WA 99164)

The 3-D scattering from axisymmetric objects illuminated by nonaxisymmetric incident acoustic fields can be computed efficiently using finite element models, in which the field variables are decomposed via azimuthal Fourier series expansions. The number of azimuthal modes needed is determined by the convergence of the decomposition of the incident field. For simple cases, the field decomposition can be described analytically. For more complex incident fields, however, a closed form azimuthal Fourier series representation of the incident field is often not possible. A pre-processing step is presented, in which the incident field is decomposed numerically at the Gauss points on the wet surface of the target. This approach makes it possible to treat general cases, such as scattering from objects included inside heterogeneous media, at shallow grazing angle, when the symmetry axis of the object is not perpendicular to the interface between the two media. Other applications include decomposing the boundary scattered field re-incident on an object. The model is applied to scattering from a 2:1 aluminum cylinder, included in a fast fluid medium above a slow fluid medium, with the source in the slow medium, and the results are compared to ultrasonic tank measurements. [Work supported by ONR/ONRG.]

8:20

1aUW2. Acoustic scattering from unexploded ordnance in contact with a sand sediment: Mode identification using finite element models. Aubrey L. España, Kevin L. Williams, Steven G. Kargl (Appl. Phys. Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, aespana@apl.washington.edu), Mario Zampolli (TNO Defense, Security and Safety, The Hague, Netherlands), David S. Burnett (Naval Surface Warfare Ctr., Panama City, FL 32407-7001), and Philip L. Marston (Washington State Univ., Pullman, WA 99164-2814)

Previous work has illustrated the potential benefit of using low frequency sound as a means for detecting and classifying objects in contact with a sand sediment. In these situations, the wavelength of sound is on the order of the object dimensions, thus coupling to the objects resonant modes. This leads to an acoustic signature rich in physical phenomena unique to the object shape and elastic properties. Hybrid 2-D/3-D finite element models have been developed for unexploded ordnance in contact with a sand sediment. Previous work has demonstrated these models are in good agreement with data collected during experiments conducted in a test pond in 2010 [A. L. España *et al.*, J. Acoust. Soc. Am. **129**, 2685 (2011)]. In this paper, the finite element models are used as a means for mode identification and physical interpretation. These modes are visualized through plots of the pressure amplitudes and displacements along the UXO

exterior and are explained using insights derived from physical acoustics. Finally, a full 3-D finite element model was developed to investigate the changes to the acoustic response in situations where the symmetry of the problem is broken and the hybrid 2-D/3-D method is no longer viable. [Research supported by ONR and SERDP.]

8:40

1aUW3. Time-domain finite element modeling of interaction of heterogeneous solids with acoustic waves. Petr Krysl (Dept. of Structural Eng., Univ. of California, San Diego, 9500 Gilman Dr., #0085, La Jolla, CA 92093, pkrysl@ucsd.edu)

The vibroacoustic finite element toolkit (VATK) utilizes a Lagrangian finite element method specifically developed for analyzing the interaction of biosolids immersed in fluids with acoustic waves. It employs a superposition principle to separate the incident acoustic wave from the scattered and radiated waves in a displacement-based finite element model. An absorbing boundary condition is applied to the perturbation part of the displacement. Linear constitutive equation allows for inhomogeneous, anisotropic materials, both fluids and solids. Displacement-based finite elements are used for all materials in the computational volume, which can be fluids, solids, and voids in arbitrary combination. Robust performance for materials with limited compressibility is achieved using incompatible-mode brick elements. A centered-difference time-stepping algorithm is formulated to handle general damping accurately and efficiently. The VATK uses a voxel-based modeling scheme for complex geometries. The modeling methodology comes with some challenges. Here we discuss the issues of verification and validation, convergence and error control, and performance of the present technique in application areas for which it was not originally intended. [Work supported by the Office of Naval Research and the Chief of Naval Operations, Environmental Readiness Division.]

9:00

1aUW4. New strategies for full-wave simulations of large acoustic models. Tomi Huttunen (Dept. of Appl. Phys., Univ. of Eastern Finland, P.O. Box 1627, FI-70211 Kuopio, Finland, tomi.huttunen@uef.fi)

The simulation of large acoustic models using conventional low-order finite element or boundary element (BE) methods can be computationally demanding due to the requirement of wavelength dependent mesh density (5-10 elements per wavelength is a typical rule of thumb). A recent improvement of finite element type methods has focused on the efficient parallelization of problems to even thousands of processors. The discontinuous Galerkin (DG) methods, in time- and frequency-domain, have been particularly popular since DG methods retain the geometric flexibility of FE methods while allowing a more flexible choice of basis functions. The locality of DG basis makes them ideal for large-scale parallelization and the choice of basis can be easily extended to non-polynomial functions such as plane waves or Bessel functions. This study focuses on the three new strategies for solving large acoustic problems. First, the non-polynomial basis functions are used with the DG method in frequency-domain problems. Second, from element to element varying polynomial order is used for the wave equation in the time-domain. And third, cloud computing is utilized for efficient resource allocation with a fast multiple BE method for the acoustic Helmholtz equation.

9:20

1aUW5. Scattering by an elastic object in the time domain for underwater acoustic applications by means of the spectral-element method. Paul Cristini and Dimitri Komatitsch (CNRS-LMA, 31 Chemin Joseph Aiguier, 13009 Marseille, France)

The increase in computational power which has been occurring during the past years makes it possible to consider the full wave simulation in the time domain of the propagation of acoustic waves in more and more complex configurations in underwater acoustics. Among the various derivations of the finite element method, the spectral-element method has proven to be an efficient and robust tool in seismology. This method combines the accuracy of the pseudospectral method and the flexibility of the finite element method. Its intrinsic properties lend itself very well to numerical simulations on parallel computers, which nowadays is a very big advantage. We will present some results obtained by means of the SPECSEM software, a freely available code which implements the spectral-element method. Its use in underwater acoustics is natural since all types of media which can be encountered in the oceanic environment have already been implemented: fluid, elastic, viscoelastic, anisotropic, and poroelastic. Some illustrative examples of the diffraction of an acoustic wave by an elastic object in various situations will be presented. In particular, a special attention will be paid to the nature of the medium in which the object is embedded.

9:40

1aUW6. Finite-element modeling of sound transmission blocking materials realized using pancake voids in a soft elastomer. David C. Calvo, Abel L. Thangawng, and Christopher N. Layman Jr. (Acoust. Div. Naval Res. Lab., Washington, DC 20375)

The fact that gas-filled voids in a soft elastomer acoustically resemble gas bubbles in a liquid (both having strong low-frequency monopole resonances) was pointed out by analysis and experiment by V. Leroy *et al.* [Appl. Phys. Lett. **95** (2009)]. The present work reports on the modeling, design, fabrication, and testing of specially designed voids in the soft elastomer polydimethylsiloxane (PDMS) with the aim of creating high performance sound transmission blocking materials. The techniques of soft lithography allow the microfabrication of custom cavity shapes in PDMS to obtain desired microstructural resonances. Results of a finite-element modeling analysis are reported that determine the monopole resonance frequencies of what we term pancake voids embedded in layers of PDMS. Because of the high aspect ratio of these voids, the low-frequency monopole (Minnaert) frequencies are between 3 and 6 times lower than that for a spherical cavity of equivalent volume inside PDMS. In terms of the potential for thin sound blocking slabs, this allows a lowering of the frequency at which blocking begins to take place. We also present modeled transmission loss results for normal incidence on an infinite array of pancake voids (a sonic crystal). [Work sponsored by the Office of Naval Research.]

10:00–10:15 Break

10:15

1aUW7. Design of inhomogeneous pentamode metamaterials for minimization of scattering. Jeffrey Cipolla, Nachiket Gokhale (Weidlinger Assoc., Inc., 375 Hudson St, New York, 10014), Andrew Norris, and Adam Nagy (Rutgers Univ.)

Acoustic metamaterials use sub-wavelength, anisotropic, and inhomogeneous microstructures. Macroscopic properties can be related to the microstructure using homogenization theory Hassani and Hinton [Comput. Struct. **69**, 719–738 (1998), which allows an analyst to confirm the extent to which a candidate metamaterial microstructure meets the requirements for a pentamode cloaking material. Norris [Proc. R. Soc. Ser. A, **464**, 2411–2434 (2008)] presented a theory of transformation acoustics that enables the realization of inhomogeneous pentamode acoustic materials having anisotropic elastic tensors, isotropic density and finite mass. This theory describes the spatially varying material properties in terms of a mapping, which for separable geometries may be generated using a scalar function. This function, the constraints on its behavior implicit in the Norris theory, and the material equations constitute the defining relations for pentamode transformation acoustics. Previously, analytic work in transformation acoustics developed the material properties after having fixed a transformation. By reversing the process, we create a number of new families of pentamode cloaking materials. We validate the concept with three-dimensional explicit transient finite element simulations.

10:30

1aUW8. Modeling of offshore wind turbine noise radiation and propagation. Huikwan Kim, Gopu R. Potty, James H. Miller, and Christopher Baxter (Dept. of Ocean Eng., Univ. of Rhode Island, Narragansett, RI 02882, hkkim524@my.uri.edu)

Noise generated by offshore wind turbine and support structure can radiate and propagate through the air, water, and sediment. Predicting noise levels around wind turbine structures at sea is required for the estimation of effects of the noise on marine life. To predict radiated noise, we used a finite element analysis (FEA) of a cylindrical shell model of a monopile structure. In the finite element modeling, transient modal dynamic analysis and steady state dynamic analysis (direct and modal) were implemented to simulate both construction and operational noise. The effect of various sediment types and foundation designs are investigated. The FEA package used was ABAQUS version 6.10. The output of the FEA analysis is used as starting field for acoustic propagation models such as PE to produce long range predictions. We present predictions of particle velocity at the structure-acoustic medium interface and sound pressure level as function of frequency at various distances from the structure. Laboratory experiments using scale models of the cylindrical shell have been carried out to verify the noise predictions. Comparison of the FEA model results and experimental data will be presented.

10:45

1aUW9. Acoustic scattering from a metallic pipe: Mode isolation and visualization via finite element analysis. Aubrey L. España, Kevin L. Williams (Appl. Phys. Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, aespana@apl.washington.edu), Philip L. Marston (Washington State Univ., Pullman, WA 99164-2814), and Mario Zampolli (TNO Defense, Security and Safety, The Hague, Netherlands)

Understanding how sound couples to, and radiates from targets, aids in finding frequencies and angles advantageous for target detection and classification. Finite element models, coupled with physical acoustics models, have been used to identify resonant modes of truncated, solid cylinders [D. B. Thiessen *et al.*, J. Acoust. Soc. Am. **129**, 2686 (2011)]. This technique is extended here to an aluminum pipe. Scattering from the pipe in the freefield is studied with a finite element model based on the decomposition of the elastic displacements and fluid pressure in a series of azimuthal Fourier modes. To facilitate elastic mode identification, the calculations for the scattered pressure from a nearly rigid pipe of identical size are subtracted coherently from the elastic model results. Plotting these “subtracted” pressure amplitudes and particle displacements on the wet surface of the pipe allows

for visualization of the elastic modes. Subsequently, the model is extended for the pipe in contact with sand, via a superposition of freefield results along with the water/sand reflection coefficient. The method is used to study the modal scattering in the presence of the interface. Where applicable, finite element results are validated by predictions from ray theory and experimental results. [Work supported by ONR.]

11:00

1aUW10. High frequency scattering properties of focused acoustic beams helpful for finite element research. Philip L. Marston (Phys. and Astronomy Dept., Washington State Univ., Pullman, WA 99164-2814)

It can be helpful to understand apparent anomalies in the scattering when developing or testing finite element computations for the scattering of sound by objects in water with the wavenumber-radius product ka of approximately 10 or greater. In the case of focused acoustic beams incident on a sphere centered in the axis of the beam, analytical results are available using the method of superposition of Bessel beams [P. L. Marston, J. Acoust. Soc. Am. **129**, 1773–1782 (2011)]. High ka analytical results can manifest an unusually large forward scattering lobe when the focal width of the beam becomes similar to the size of the sphere. (This is in contrast to the examples of scattering at relatively small ka illustrated in the aforementioned reference.) This new behavior can be understood by considering the definition of the total wave field as the superposition of the incident and the scattered fields combined with reasoning based on geometry, the localization principle, and other high frequency approximations. It is likely that high ka finite element computations of the scattering by narrowly focused beams for other shapes of objects will manifest a correspondingly enhanced scattering lobe. [Research supported by ONR.]

11:15

1aUW11. Numerical model of nonlinear acoustic wave propagation in seabed. Rana Arslan A. Khan and Grant A. Ellis (Dept. of Elec. Eng., Univ. Teknologi PETRONAS, 31750 Tronoh, Perak, Malaysia, rarslana@gmail.com)

In this study, a combination of two fundamental frequencies $f_1 = 485$ KHz and $f_2 = 515$ KHz. The source transducers are placed on the surface of the sand 25 cm above the bottom and 20 cm below the water surface in the tank of dimension $74 \times 47 \times 43.5$ cm simulating a seabed with sand of maximum particle size of 5 mm. Burger’s equation is the simplest model for describing the second order nonlinear effects in the propagation of high amplitude plane waves and, in addition, the dissipative effects in media. Typically, the interactions of two acoustic waves at a discontinuity in a dispersive but homogeneous medium will generate harmonics and intermodulation terms. This is numerically modeled in MATLAB using the finite difference time domain method with Neumann boundary conditions and practically verified with measurements from the tank. The measured and simulated results have shown significant agreement with the theory. For instance, second order intermod term show 2 dB decreases in amplitude for 7 mm increase in thickness at constant density of plywood. Also if the thickness is kept same, e.g., 5 mm, there is 10 dB drop in same intermod term for change in density from plywood 550 kg/m^3 to copper 8930 kg/m^3 .

11:30

1aUW12. Characterization of scattered acoustic intensity fields of finite cylinders in the resonance region. Robert J. Barton III, Geoffrey R. Moss (Naval Undersea Warfare Ctr., code 1522, 1176 Howell St., Newport, RI 02841, robert.barton@navy.mil), and Kevin B. Smith (Naval Postgrad. School, Monterey, CA)

The properties of the scattered acoustic vector fields generated by infinite-length and finite rigid and elastic cylinders are investigated. Analytical solutions are derived from general acoustic pressure scattering models and analyzed for wave numbers in the resonance region. The separable active and reactive components of the acoustic intensity are used to investigate the structural features of the scattered field components. Numerical results are presented for the near and transition regions. A finite element model is

developed for a rigid cylinder and compared to measured results in-air using an anechoic chamber and acoustic vector sensor probes to measure the scattered acoustic vector field. The finite cylinder model and analysis is then

extended to include an evacuated thin-walled elastic shell. The vector properties of the time-independent complex intensity components and their relations to field energy density quantities are summarized.

MONDAY AFTERNOON, 31 OCTOBER 2011

SUNRISE, 1:15 TO 5:20 P.M.

Session 1pAA

Architectural Acoustics and Psychological and Physiological Acoustics: Architectural Acoustics and Audio I

K. Anthony Hoover, Cochair

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

Alexander U. Case, Cochair

Fermata Audio & Acoustics, P.O. Box 1161, Portsmouth, NH 03802-1161

Chair's Introduction—1:15

Invited Papers

1:20

1pAA1. Bollywood sound stages. K. Anthony Hoover (McKay Conant Hoover, Inc., 5655 Lindero Canyon Rd., Ste. 325, Westlake Village, CA 91362)

Sound for bollywood films is rarely recorded live on location, but is looped or added later, in large part because of poor ambient acoustics. Several new sound stages in Film City, Mumbai, India, were intended for "Hollywood" quality acoustics, but construction ceased shortly after starting. Then, after several years' hiatus, the project was renewed with the directive that the existing fragmentary construction be used in the new design and as the foundation for subsequent construction. This paper will discuss the background, site conditions, encroaching hutments, design issues, concerns for local materials and methods, and the results of post-construction acoustical testing.

1:40

1pAA2. Case study: Active acoustics at the Barbara Streisand scoring stage. Steve Ellison (Meyer Sound Labs., 2832 San Pablo Ave., Berkeley, CA 94702, ellison@meyersound.com), Shawn Murphy, and David R. Schwind (Charles M. Salter Assoc., Inc., San Francisco, CA 94104)

Scoring stages are recording studios large enough to accommodate an orchestra, and typically used to record music sound tracks for films. The acoustic properties and goals of scoring stages are reviewed, and compared with other venue types. Recently, an active acoustics system was installed in the Barbara Streisand scoring stage on the Sony lot in Culver City, California. The system was used to electronically vary the reflected sound and reverberation during the recording of several film scores. The objectives, design, and performance of the system in the room is reviewed. The range of settings and controls provided to the scoring mixer are described as well as the process used to select parameters for different aspects of the score. These had implications on the artist performance as well as the recording and mixing process. The resultant reverberation times achieved are compared with archetypical orchestral performance venues as well as other scoring stages.

2:00

1pAA3. Case study: Multipurpose venue at Berklee College of Music. Raunak Mukherjee and Eric Reuter (Music Production and Eng./Liberal Arts Dept., Berklee College of Music, Boston, MA 02215, rmukherjee@berklee.net)

This 90 m² square meter multipurpose venue was intended to host a variety of programs, including musical performance, lecture, yoga, and dance instruction, etc. Most of these employ a built-in sound reinforcement systems. However, since its construction, the room has suffered from excessive reverberation, making it unsuitable for most of these intended uses, even with reinforcement. Venues of this type demand a balance between speech clarity and a level of reverberation sufficient to support musical performance. The authors will present a detailed acoustical analysis of the room at the start of the project, the goals of the design, and specific recommendations for acoustical treatment.

2:20

1pAA4. Design guidelines for rooms used for music, speech, and teaching. Peter D'Antonio (RPG Diffusor Systems, Inc., 651-C Commerce Dr., Upper Marlboro, MD 20774, pdantonio@rpginc.com) and Christian Nocke (Akustikbüro Oldenburg, Oldenburg, DE D-26121)

Good architectural acoustic design requires an appropriate combination of absorptive, reflective and diffusive surfaces, providing attenuation, redirection, and uniform scattering. Since the terms acoustical and absorptive have become synonymous in common parlance,

education of the architectural design community is needed to understand the use of reflective and diffusive surfaces in spaces used for speech, music rehearsal and performance, and teaching. For example, in speech and teaching rooms, where the signal to noise ratio and associated intelligibility are the central issues, designs must not only lower the noise with absorption and isolation but also passively increase the signal with diffusion/reflection. In music education and rehearsal spaces, absorptive low frequency and volume control are important, but reflection/diffusion is equally important for ensemble, tone production and intonation control. In an effort to develop design guidelines, we will review the German standard DIN 18041 on "Acoustic Quality in small and medium sized rooms" (1968, 2004), which standardizes performance objectives in rooms with a volume up to 5000 cbm used for music, speech, and teaching. A frequency and volume dependent suggestion for the reverberation time will be presented as a function of the volume index and examples will be provided.

2:40

1pAA5. Active acoustics used in existing spaces for music practice. Ron Freiheit (Wenger Corp., 555 Park Dr. Owatonna, MN 55060, ron.freiheit@wengercorp.com)

For a number of years, modular practice rooms have offered the option of active acoustics technology as part of their integrated learning environment for music. This approach was effective, in part, because the interior acoustics of each room were well-defined with regard to reverberation time, background noise, and sound isolation. The desire to retrofit existing practice and music teaching spaces with active acoustics introduces numerous challenges. These include addressing environmental limitations (such as unencumbered physical locations for speakers and microphones) and the acoustic environment (issues of sound isolation, reverberation time, and background levels). This paper will explore how these challenges were addressed and how compromises were reached.

3:00

1pAA6. Extending the acoustical versatility of large performing arts classrooms. Robert M. Brenneman and David A. Conant (McKay Conant Hoover, Inc., 7435 E. Stetson Dr., Ste. A, Scottsdale, AZ 85251, rbrenneman@mchinc.com)

To accommodate an extensive array of performing arts programs with limited financial and facility resources, learning institutions often desire a high-degree of acoustical versatility within their larger classroom performance spaces. For the acoustician, achieving quality room acoustics in a singular space suitable for lecture, performance, and application of performance technologies can pose a significant challenge. The large multi-purpose performing arts classroom at Mesa Community College's Red Mountain Campus demonstrates how careful selection of sound absorptive materials, shaping of sound reflective surfaces, material placement, and employment of variable acoustics methods including novel, custom gobos can provide a diverse acoustical environment for addressing the varying acoustical needs of dance, music, and theater departments. This paper presents the cost-effective and practical materials and methods utilized within this multi-purpose performing arts classroom for its use as a teaching, drama, dance, and music performance space for virtually all music genres, from jazz to renaissance choral works.

3:20–3:30 Break

3:30

1pAA7. Subwoofer optimization in rooms for consistency and efficiency. Todd S. Welti (Corporate RD Dept., Harman Int., 8500 Balboa Blvd., Northridge, CA 91329, todd.welti@harman.com)

Early work on optimizing subwoofer placement in rooms focused on trying to minimize variations in sound power response by optimizing room dimensions. Some consideration has also been given to maximizing overall sound power output, typically by putting subwoofers in room corners. Recent research using a sophisticated computer model has instead focused on trying to minimize variation of magnitude response from seat to seat. Using the same computer model, optimal subwoofer configurations are identified, which give consistent seat to seat responses and maximize low frequency efficiency. Consideration is given to different room dimensions and different seating configurations. The resulting plots may be very useful in designing small rooms with full range audio playback systems and multiple seats.

3:50

1pAA8. On a variable broadband absorption product and acceptable tolerances of reverberation times in halls for amplified music. Niels Werner Adelman-Larsen (Flex Acoust., Scion DTU, Diplomvej 377, Kgs. Lyngby, Denmark, nwl@flexac.com), Jens Joergen Dammerud (Nordic Inst. for Stage and Studio, Oslo, Norway), and Eric R. Thompson (Boston Univ.)

Previous studies have shown that what distinguishes the best from the less well liked halls for pop and rock music is a short reverberation time in the 63, 125, and 250 Hz octave bands. Since quite long reverberation times in these frequency bands are needed in order to obtain warmth and enough strength at classical music concerts, variable acoustics must address these frequencies in order to obtain desirable acoustics in multipurpose halls. Based on the results of a previous study of Danish rock venues as well as reports from three newly built halls, acceptable tolerances of T30 were investigated. The results suggest that T30 can be at least 1.8 times as long in the 63 Hz octave band as in the 125 Hz band and attain values of +/- 15% at higher frequencies compared to the previously determined values. A variable broadband absorption product is also presented. Absorption coefficients are approx. 0.8 in the 125, 250, and 500 Hz bands, 0.6 at 1 kHz and decreasing at higher frequencies, and in the 63 Hz band when in the ON position. In the OFF position the product attains absorption values between 0.0 and 0.2.

4:10

1pAA9. Glass as an aid and as a challenge in acoustics treatment. Sergio Beristain (E.S.I.M.E., IPN, Lab. Acoustics, IMA, Mexico City, Mexico, sberista@hotmail.com)

A new installation for a broadcast center that included recording and transmission studios had to be constructed in an all transparent glass façade building in a major street in Mexico City. Together with all the acoustical specifications requested and needed for proper response of the studios, it was also requested from the very beginning of the project that the building façade could not be modified at all,

i.e., all the glassing could not be obstructed in at least a couple of meters from the edge of the building in order to preserve the look of the building as it was originally constructed. This meant that enough sound insulation for the studios and control rooms as well as the short reverberation times, and resonance control needed by the acoustic conditioning treatment had to be attained with plenty of glass area, which could not be moved, plus all the glassing needed for visual communication between rooms to allow for normal operation of the studios. Construction details and results are presented.

4:30

1pAA10. Cost-effective evaluation of different residential hard-surfaced flooring and underlayment systems. Marlund E. Hale (Adv. Eng. Acoust., 663 Bristol Ave., Simi Valley, CA 93065, mehale@aol.com)

There is increasing interest in replacing carpeted flooring with hard-surfaced flooring. Changing from soft-surfaced to hard-surfaced floors always results in an increase in the liveness of hard-flooring rooms and increased impact noise in lower rooms due to reduced impact isolation performance of the revised floor/ceiling assembly. An effective underlayment between the subfloor and the hard-surfaced flooring must be carefully selected and evaluated for ultimate compliance with floor/ceiling assembly performance requirements. In addition, any overall increase in flooring thickness is a major concern. This paper presents optimized field performance testing of several condominiums in a luxury multi-family residential complex for which the homeowner's association had set strict performance and testing requirements. Failure meant restoring the flooring to its original condition. A series of *in situ* and special field tests were undertaken to assist in the selection of qualifying underlayment systems for the desired hard-surfaced flooring. *In situ*, client-preferred, flooring samples were installed by the respective flooring contractors. Special field tests that involved the preferred systems and other flooring/underlayment combinations were conducted in a vacant two-story residence. In the *in situ* and vacant testing locations, the respective variables at each location were the different flooring and multiple underlayment systems.

Contributed Papers

4:50

1pAA11. The practical effects of mixing in an environment closely resembling a home listening environment. Richard King, Brett Leonard, and Grzegorz Sikora (Graduate Program in Sound Recording, Ctr. for Interdisciplinary Res. in Music Media and Technol., Schulich School of Music, McGill Univ., 555 Sherbrooke St. West, Montreal, QC H3A1E3)

Two traditional philosophies exist when considering recording studio control room design: the method of closely replicating the listening environment of the consumer, quite often the typical living room, as juxtaposed to the idea that the control room should be uniquely suited toward color-free critical listening. While both of these design philosophies have had their proponents and detractors, very little data have been gathered to show the merits or drawbacks of either when used for critical recording and mixing work. A novel method of task-based testing is developed to determine what, if any, affects can be attributed to particular aspects of control room designs. The method employs highly trained recording engineers and producers to provide real-world feedback on the makeup of a control room's sidewalls. By having these trained subjects to perform basic mixing tasks while altering the reflectivity and diffusiveness of the sidewalls, the effects of these isolated acoustic features are determined. Data showing the final balance levels, as well as total elapsed time per trial, are recorded from more than 20 expert subjects. Despite strong differences in lateral reflected

energy, most subjects were able to perform their task with relatively little variance.

5:05

1pAA12. The insertion loss of plenum windows with non-parallel line sources. Y. G. Tong (Dept. of Construction Eng. & Architecture, Univ. Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johore, Malaysia, ygtong@uthm.edu.my) and S. K. Tang (The Hong Kong Polytechnic Univ., Hong Kong, China)

Opened window for natural ventilation becomes difficult to implement for the buildings in densely populated cities due to traffic noise problem. An experimental investigation of plenum window which was staggered inlet and outlet openings to allow natural ventilation through itself was studied. A 1:4 scale down model was adopted in the study to estimate the acoustical insertion loss of plenum windows in the presence of stimulated non-parallel line source. The orientations of plenum window relative to the traffic roads are found to be significant in protecting from transportation noise due to the staggered design. About 15 dBA of acoustical benefits can be obtained by studied ventilation window system compared to the opened window. The minimum insertion loss was recorded around 6 dBA when the tested window was placed perpendicularly to the line source. [Y.G. Tong sponsored by Ministry of Higher Education, Malaysia.]

Session 1pAOa

Acoustical Oceanography, Underwater Acoustics, and Animal Bioacoustics: Van Holliday Memorial Session II

Whitlow W. L. Au, Cochair

Marine Mammal Research Program, Hawaii Inst. of Marine Biology, Univ. of Hawaii, Kailua, HI 96734

Kelly J. Benoit-Bird, Cochair

College of Ocean and Atmospheric Science, Oregon State Univ., 104 COAS Admin Bldg., Corvallis, OR 97331-5503

Michael J. Buckingham, Cochair

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

Timothy K. Stanton, Cochair

Dept. of Applied Ocean Physics and Engineering, Woods Hole Oceanographic Inst., Bigelow 201, Woods Hole, MA 02543-1053

Contributed Papers

1:00

1pAOa1. Relationship between volume backscatter from the mesopelagic boundary community and density of organisms in the waters of the Hawaiian Islands. Whitlow W. L. Au, Marc O. Lammers (Hawaii Inst. of Marine Biology, Univ. of Hawaii, 46-007 Lilipuna Rd., Kaneohe, HI 96744), and Jakob Jung (Bremen Univ. of Appl. Sci.)

Spinner dolphins in the near-shore waters of the Hawaiian islands forage on a mesopelagic boundary community of organisms consisting of myctophids, mid-water shrimps, and small squids. To better understand the foraging ecology of spinner dolphins, it is important to understand the relationship between volume scattering coefficient (Sv) obtained with an echosounder and the density of the organisms in the mesopelagic boundary community. A suite of Simrad Ek-60 scientific echosounders operating at 38, 72, 120, and 200 kHz directed vertically downward was used to collect volume backscatter data from a vessel anchored 1 km from shore. Sv tended to be highest at 38 kHz and lowest at 200 kHz, although at some depths Sv at 70 kHz was slight higher than at 38 kHz data. Immediately after collecting the echosounding data, a profiler with a broadband high-resolution echo ranger projecting a simulated dolphin biosonar signal horizontally was lowered into the same volume examined by the EK-60. The number of organism in the echoranger beam out to a specified range was estimated by counting the number of highlights in the echoes after performing an envelope detection. The relationship between Sv and number of organisms was found to be linearly related.

1:15

1pAOa2. Temporal and spectral feature extraction from fish school using a broadband split-beam echosounder. Masanori Ito, Ikuo Matsuo (Tohoku Gakuin Univ., Tenjinzawa 2-1-1, Izumi-ku, Sendai 981-3193, Japan), Tomohito Imaizumi, Tomonari Akamatsu (Natl. Res. Inst. of Fisheries Eng., Hasaki, Kamisu, Ibaraki 314-0408, Japan), Yong Wang, and Yasushi Nishimori (Furuno Electric Co., Ltd., Nishinomiya, Hyogo 662-8580, Japan)

For sustainable fisheries, remote discrimination of fish species has been demanded recently. Features for fish discrimination should be extracted from schools. High spatial resolution of broadband split-beam echosounder system enabled tracking individual fish in a school. Temporal and spectral features such as waveform envelopes and target strength spectra were

calculated individually. In addition, incident angles of sound were calculated by using positions and velocities of a fish, which were measured by the tracking process of the four channels split-beam system. Because the acoustical features from individual fish depended on the incident angles of sound, all feature parameters were sorted according to the angles to create temporal and spectral averaged pattern. In free ranging condition, echoes of Japanese jack mackerel (*Trachurus japonicus*), chub mackerel (*Scomber japonicus*), and red sea bream (*Pagrus major*) were measured. Results showed clear difference among temporal and spectral averaged patterns, which was consistent with test measurement obtained in an acoustic tank. Broadband split-beam system seemed to be appropriate to extract species specific feature in the ocean. [Work supported by the Research and Development Program for New Bio-industry Initiatives.]

1:30

1pAOa3. Feature extraction for discrimination of fish species by using the cepstral analysis. Ikuo Matsuo, Masanori Ito (Tohoku Gakuin Univ., Tenjinzawa 2-1-1, Izumi-ku, Sendai 981-3193, Japan), Tomohito Imaizumi, Tomonari Akamatsu (Natl. Res. Inst. of Fisheries Eng., Ibaraki 314-0408, Japan), Yong Wang, and Yasushi Nishimori (Furuno Electric Co., Ltd., Hyogo 662-8580, Japan)

Identification and classification of fish species are essential for acoustic surveys of fisheries. The echo from the fish contains components from multiple reflections, including the swimbladder and other organs. The target strength (TS) and temporal structure, which were measured and analyzed by using the broadband signal, were changed dependent on the incident angles and fish species. It has been shown that these features were important for discrimination of fish species. The incident angles were calculated by using positions and velocities of each fish, which were measured by the tracking process of the four channels split-beam system, and the target strength was calculated individually by using Fourier transform. In this paper, the cepstral analysis, which was defined as the inverse Fourier transform, was used to extract features for discrimination of fish species from the broadband spectral pattern. In free ranging condition, echoes of Japanese jack mackerel (*Trachurus japonicus*), chub mackerel (*Scomber japonicus*), and red sea bream (*Pagrus major*) were measured and analyzed. It was examined whether cepstral analysis was appropriate to extract species specific features. [Work supported by the Research and Development Program for New Bio-industry Initiatives.]

1:45

1pAOa4. Statistics of echoes from mixed assemblages of scatterers with different scattering strengths and numerical densities. Wu-Jung Lee and Timothy K. Stanton (Dept. of Appl. Ocean Phys. and Eng., Woods Hole Oceanograph. Inst., Woods Hole, MA 02543, wjlee@whoi.edu)

Mixed assemblages are defined to describe the cases in which more than one type of scatterer are present and are randomly located and spatially interspersed among one another in each sonar resolution cell. The probability density functions (pdfs) formed by the echo envelopes in such cases can be highly non-Rayleigh and possess heavy tails. The shape of the pdf curves contains information for characterizing and discriminating the composition of mixed assemblages. A general characteristic-function-based mixed assemblage pdf model is formulated in this study. The model, which takes into account beampattern effects, was validated using numerical simulations. Simulated data of two-component mixed assemblages with different relative scattering strengths, numerical densities, and spatial distributions were used to compare the performance of this new mixed pdf model and the widely used weighted multiple component mixture pdf model. It was found that use of the latter model can lead to orders of magnitude errors in estimating the composition of the mixed assemblages. This study is inspired in the context of acoustic studies of mixed biological aggregations in the ocean, but the theory is generally applicable to other types of mixed assemblages as well.

2:00

1pAOa5. Spatial variation in the small-scale distribution of juvenile walleye pollock (*Theragra chalcogramma*) in the southeastern Bering Sea. Neal E. McIntosh, Kelly J. Benoit-Bird (College of Oceanic and Atmospheric Sci., Oregon State Univ., 104 COAS Admin Bldg., Corvallis, OR 97331, nmcintosh@coas.oregonstate.edu), and Scott A. Heppell (Dept. of Fisheries and Wildlife, Oregon State Univ., 104 Nash Hall, Corvallis, OR 97331)

Juvenile walleye pollock (*Theragra chalcogramma*) is one of the primary prey items for bird and mammal predators in the Bering Sea and supports a large commercial fishery. An understanding of the abundance and distribution of juvenile pollock is needed to estimate the effects that change in these parameters may have on pollock predators and adult pollock abundance and distribution. During the summers of 2008 and 2009, surveys were conducted in three topographic zones (Middle Shelf, Outer Shelf, and Slope) near the Pribilof Islands in the southeastern Bering Sea. Multi-frequency (38, 70, 120, and 200) acoustic sampling occurred during the entire cruise duration with frequent environmental data sampling (e.g., temperature, salinity, dissolved oxygen, and chlorophyll *a* fluorescence) and targeted fish tows. These data showed that juvenile walleye pollock were primarily found in clusters of small, dense aggregations giving them a leopard spot appearance in the acoustical output. In both years, juvenile pollock distribution was highly variable on small spatial scales and was related to biological and physical features of the water column. These differences in juvenile walleye pollock distribution are likely to affect the use of habitat by predators and may have implications for future sampling.

2:15

1pAOa6. Estimating Atlantic Bluefin Tuna number density using the second moment of intensity. Madeline L. Schroth-Miller, Thomas C. Weber (Ctr. for Coastal and Ocean Mapping, Univ. of New Hampshire, 24 Colovos Rd., Durham, NH 03824, mmiller@ccom.unh.edu), and Molly Lutcavage (Univ. of Massachusetts, Amherst)

Fish number density can be estimated from the normalized second moment of acoustic backscatter intensity [Denbigh *et al.*, J. Acoust. Soc. Am. **90**, 457–469 (1991)]. This method assumes that the distribution of fish scattering amplitudes is known and that the fish are randomly distributed following a Poisson volume distribution within regions of constant density. It is most useful at low fish densities, relative to the resolution of the acoustic device being used, since the estimators quickly become noisy as the number of fish per resolution cell increases. The method was applied to an acoustic assessment of juvenile Atlantic Bluefin Tuna, *Thunnus thynnus*. The data were collected using a 400 kHz multibeam echo sounder during the summer month of 2009 in Cape Cod, MA. Due to the high resolution of

the multibeam system used, the large size (approx. 1 m) of the tuna, and the spacing of the fish in the school, we expect there to be low fish densities relative to the resolution of the multibeam system. Results based on the normalized second moment of acoustic intensity are compared to fish packing density estimated using aerial imagery that was collected simultaneously.

2:30

1pAOa7. Forward scattering at low acoustical frequencies from schools of swim bladder fish. Maria Paz Raveau and Christopher Feuillade (Pontificia Universidad Católica de Chile, Ave., Vicuña Mackenna 4860, Santiago, Chile)

Low frequency acoustic scattering from swim bladder fish is dominated by the bladder resonance response. At near-resonance frequencies in dense schools of these fish, acoustical interactions between the fish can cause the ensemble scattering behavior to become highly complex. A school scattering model [J. Acoust. Soc. Am. **99**(1), 196 (1996)] has previously been developed to incorporate both multiple scattering effects between neighboring fish, and coherent interactions of their individual scattered fields, in order to realistically describe the collective back scattering behavior of fish schools. In this present work, the school scattering model has been extended to investigate the properties of the acoustic field scattered in the forward direction. In this region, the scattered field and the incident field must be added coherently to obtain the total field. As in the case of back scattering, the field displays marked frequency dependent effects, which are caused by different combinations of the packing density, structural configuration, and resonance frequencies of the individual fish in the school. The results give new insights into the evolution of the acoustic field as it propagates through the school, and the scattering of sound from the incident beam. [Work supported by ONR.]

2:45–3:00 Break

3:00

1pAOa8. Acoustic cross sections and resonance frequencies of large fish schools. Thomas R. Hahn (Great Lakes Ctr., Buffalo State, SUNY, 1300 Elmwood Ave., Buffalo, NY 14222, hahntr@buffalostate.edu) and Orest Diachok (Johns Hopkins Univ. Appl. Phys. Lab., Laurel, MD 20723)

A prerequisite for stable inversion of bioacoustic parameters of fish schools from large-scale broadband acoustic observations is a theoretical model that permits fast and accurate calculations of acoustic cross sections and school resonance frequencies based on realistic geometrical models of fish schools. The schools of commercially important species, such as sardines, anchovies, and herring, may be characterized by dense nuclei which contain tens of thousands of individuals (*N*) with separations (*S*) on the order of one fish length, and diffuse “fuzz” regions with fish at significantly larger separations. Numerical computations of cross sections and school resonances based on the fundamental equations of multiple scattering for point scatterers for these fish school geometries will be presented. Initial results indicate that bubble cloud frequencies of large schools depend primarily on the average spacing between fish in the nuclei and are essentially independent of school size and shape. It will be shown that theoretical calculations of bubble cloud frequencies (based on previously reported values of *N* and *S* of sardine schools) are consistent with Diachok’s (1999) observations of the average resonance frequency of sardine schools which were derived from broadband transmission loss measurements. [Work is supported by the Office of Naval Research.]

3:15

1pAOa9. Mid-frequency backscatter from spatially organized fish schools. Thomas C. Weber, Madeline L. Schroth-Miller (Ctr. for Coastal and Ocean Mapping, Univ. of New Hampshire, Durham, NH 03824, weber@ccom.unh.edu), Molly Lutcavage (Univ. of Massachusetts, Gloucester, MA 01930), Shachak Pe’eri, and Yuri Rzhanov (Univ. of New Hampshire, Durham, NH 03284)

Schools of Atlantic bluefin tuna, *Thunnus thynnus*, can exhibit highly organized spatial structure. A stochastic simulation has been used to investigate the impact of this spatial structure on the backscattered acoustic field at frequencies below 10 kHz. The simulations are seeded with realizations of schools of juveniles based on field observations from 2009 in Cape Cod

1p MON. PM

Bay. The field observations, which consist of both aerial imagery and 400 kHz multibeam echo sounder backscatter, have been used to characterize the school morphology, number of fish, and spatial structure within the school. The simulation examines various degrees of structure within the school, starting with fish locations that are constrained by the school boundaries but are otherwise the result of a Poisson process, and gradually incorporating components of school structure such as nearest neighbor distance and quasi-crystalline school sub-structures containing different numbers of fish. Results of the simulation suggest that multiple scattering is negligible except at low frequencies near the swimbladder resonance. Above resonance, even a modest degree of structure within the school (e.g., spatial constraints on pairs of fish) results in appreciable changes to the scattered field. [Work supported by ONR.]

3:30

1pAOa10. Calculations of coherent backscatter enhancement from aggregations of underwater scatterers. Adaleena Mookerjee and David R. Dowling (Dept. of Mech. Eng., Univ. of Michigan, Ann Arbor, MI 48109-2133)

Coherent backscattering enhancement (CBE) is a multiple scattering phenomenon that occurs in optics and acoustics. For plane wave illumination of an aggregation of randomly placed omni-directional scatterers, CBE may lead to as much as a doubling of the scattered field intensity in the direction opposite that of the incident wave. This presentation compares different calculation techniques for CBE for plane-wave harmonic incident sound fields scattered from N underwater bubbles. The first calculation technique is based on the classical field theory of Foldy (1945) for point scatterers and is equivalent to a boundary-element calculation that uses one element per scatterer and requires inversion of a fully populated $N \times N$

matrix. The second calculation is based on the finite element method and involves inversion of a larger but more sparsely populated matrix, but it allows for the possibility of greater scatterer complexity. Results from both approaches are compared and contrasted for idealized underwater remote sensing scenarios involving different incident-wave frequencies, scatterer cross sections, and ranges from the scatterer aggregation to the receiving array. The eventual goal of this effort is to understand and predict CBE from fish schools. [Work supported by the Office of Naval Research.]

3:45

1pAOa11. The potential of bioacoustic absorption spectroscopy for long term monitoring of fish populations in the ocean. Orest Diachok (11100 Johns Hopkins Rd., Laurel, MD 20723-6099)

Bioacoustic absorption spectroscopy (BAS), which exploits frequency selective attenuation due to swim bladder resonances, could be incorporated into ocean observatories for long term monitoring of fish populations. BAS measurements employ environmentally friendly source levels (170 dB) and provide unbiased (by avoidance and proximity to boundaries) estimates of number densities versus fish length (and with ancillary information, species). The BAS II experiment, which was conducted in the Santa Barbara Channel, and employed a fixed ultra-broadband (0.3–10 kHz) source and a fixed vertical hydrophone array separated by 4 km, demonstrated the power of this method. Observed absorption lines in frequency/depth space were consistent with theoretically calculated resonance frequencies of directly sampled year classes of sardines and anchovies, OConnell's (1955) measurements of the dimensions of the swim bladders of these species, and echo sounder measurements of layer depths. Strategies for incorporating BAS measurements into existing fish monitoring methods will be addressed. [This research was supported by the Office of Naval Research.]

MONDAY AFTERNOON, 31 OCTOBER 2011

PACIFIC SALON 4/5, 1:00 TO 5:05 P.M.

Session 1pAOB

Acoustical Oceanography and Underwater Acoustics: Steven Schock Session on Acoustic Bottom Characterization and Subbottom Imaging Including Buried Objects

Altan Turgut, Cochair

Naval Research Lab., Acoustics Div., 4555 Overlook Ave., SW, Washington, D.C. 20375

Dajun Tang, Cochair

Applied Physics Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105-6698

Chair's Introduction—1:00

Invited Papers

1:05

1pAOB1. The evolution of the chirp sonar high resolution sub-bottom sonar. Lester R. LeBlanc (Dept. of Ocean Eng., Florida Atlantic Univ., Boca Raton, FL, lleblanc6@cfl.rr.com) and Larry A. Mayer (Univ. of New Hampshire, Durham N.H. 03824)

Professor Steven G. Schock completed his Ph.D. Graduate program of studies under our guidance in the Department of Ocean Engineering, University of RI. The Chirp Sonar research project that supported Stevens graduate studies was proposed to, and supported by ONR (Dr. Joseph Kravitz) in the early 1980s. The PIs were Professors Lester Leblanc (Ocean Engineering) and Professor Larry Mayer (Ocean Engineering and Geological Oceanography). Dr. Mayer and I shared a common interest in improving the quality of sub-bottom sonars so as to provide high quality quantitative data for imaging and classification of the sea floor. It was Stevens' hard work at programming the signal processing and assembling and building of components to the chirp sonar that greatly contributed to making this program a success. The initial system, housed in two large racks was tested by Steven in Narragansett Bay RI, and unprecedented high resolution images of the sub-bottom seafloor were generated with the data collected for his research program. This paper will present the theory and technological development of the chirp sonar from the early days to the present transitioned systems that are built, improved, and maintained commercially.

1pAOb2. Steve Schock and the Narragansett Bay Project. Kenneth M. Walsh (K+M Eng. Ltd., 51 Bayberry Ln., Middletown, RI 02842, kwash4@mindspring.com)

One of the first tasks for Steve Schock's sub bottom measurement system was with the Naval Undersea Warfare Center at Newport, RI. A research CRADA was established between NUWC and Precision Signals (Dr. LeBlanc and Dr. Schock) to measure the bottom sediment beneath the torpedo test range. The measurements were successful. The bay at the test range was measured down to bed rock at 64 m. The results indicated that the bay had been a glacial lake from the time the ice receded; until the sand bar that blocked the mouth of the bay eroded and the lake became a salt water bay, open to the ocean. Dr. Schock and Dr. LeBlanc authored a number of technical papers detailing the technology and its application. They founded the Chirp Lab at Florida Atlantic University in Boca Raton, Florida, where the technology has been advancing. Some of the latest techniques were presented in a special session at the May 2011 ASA meeting in Seattle.

1pAOb3. Now you see it, now you don't: Chirp imaging of the intermittently shelly shoreface ravinement surface on the inner shelf of Panama City, Florida. John A. Goff (Inst. for Geophys., Jackson School of Geosciences, Univ. of Texas at Austin, 10100 Burnet Rd., R2200, Austin, TX 78758, goff@ig.utexas.edu)

Reconnaissance CHIRP data and vibracores were collected on the inner shelf off Panama City, Florida, in April, 2011, for the purpose of providing seabed characterization for an upcoming ONR acoustic reverberation experiment. The seafloor in this region is part of the MAFLA sand sheet: Holocene shelfal marine sands, 0–5 m thick, extending from Mississippi to the Florida panhandle. Coring often samples a thin shelly layer, associated with the shoreface ravinement, at the base of the sand sheet, followed by finer-grained estuarine sediments. Prior CHIRP data collected by Steve Schock off nearby Fort Walton Beach revealed a highly intermittent reflector that could be correlated to the base of the sand sheet; whether the reflector is caused by the estuarine sediments or the shells was uncertain. The new data also reveal an intermittent basal reflector. Estuarine layering can also be identified, and in parts of our survey area the basal and estuarine horizons are distinct. A core at one of these locations sampled a 0.5-m thick shell layer corresponding to the basal reflector with sand both above and beneath. Shells are therefore likely responsible for this intermittent reflector, and thus themselves likely very heterogeneous in concentration at the ravinement surface.

1pAOb4. Application of chirp technology in earth science: From sediment dispersal to acoustic trenching of faults. Neal Driscoll (Scripps Inst. of Oceanogr., Univ. of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093) and Graham Kent (Univ. of Nevada, Reno, Reno, NV 89557)

CHIRP technology developed and perfected by Steve Schock and others allows scientists to image the earth at the scale processes shape it. Here, we present CHIRP images from a number of different tectonic and depositional settings. One example is from the Salton Sea, where we discovered faults near the southern end of the San Andreas Fault. Rupture on these newly discovered step-over faults has the potential to trigger large earthquakes on the southern San Andreas Fault (M7.5). Using the CHIRP technology to conduct "acoustic trenching" has revolutionized the study of paleoseismology and geohazards. Another example of CHIRP technology is from the continental shelf edge, offshore the US East Coast where large tensional cracks are observed (~4 km long and 1 km wide) and they might mark the location of the next slope failure along the margin. Even though rare, slope failure along the continental margin may lead to tsunami generation along the US East Coast. Sedimentary layers are the recorder of earth history and CHIRP technology allows us to image and decipher the origin of these layers in terms of climate change and tectonic deformation. The development of this technology is clearly one of the big advancements in subsurface geophysical imaging.

Contributed Papers

1pAOb5. Can slowly varying sediment layers respond acoustically like a discrete target? Charles W. Holland (Appl. Res. Lab., State College, The Penn State Univ., PA 16804) and Dale D. Ellis (DRDC, Atlantic Dartmouth, NS, Canada)

One of the most challenging issues in active sonar is the discrimination of targets from clutter. In bottom-limited areas, one of the primary sources of clutter is from the seabed. An important source of seabed clutter is discrete objects that may lie on or under the sediment interface. It is clear that target-like scattered returns should arise from discrete features that have a spatial scale, or scattered response with time scales of order of the target of interest. The intent of this research is to show that in certain cases, slowly and continuously varying sediment layers can also lead to a target-like response. This is not an intuitive cause of clutter, and the physical mechanisms that lead to the target-like response are expounded.

1pAOb6. Physics-based inversion of high-frequency multibeam sonar data. Darrell Jackson and Brian T. Hefner (Appl. Phys. Lab., Univ. of Washington, Seattle, WA 98105)

This work follows a path begun by other investigators toward physics-based inversion of sonar data. Data were acquired as part of the GulfEx11

experiment using a Reson 7125 multibeam sonar mounted on a vessel in a four-point mooring. One important feature of this effort is the simultaneous acquisition of ground-truth on seafloor properties, including sound speed, attenuation, and roughness. In addition, several frequencies, spanning 150–450 kHz, were used. As typical of this approach, a model is used to generate echo intensity time series including scattering by both seafloor roughness and volume heterogeneity. The model parameters are adjusted to provide a match to data, yielding estimates of acoustic impedance, attenuation, volume scattering strength, and roughness spectral parameters. Volume scattering is treated using an empirical model, while roughness scattering is treated using the small-slope approximation. The narrow beamwidths of sonars of this type facilitate separation of the roughness and volume signals, but pose a challenge with regard to compensation for variations in pitch and roll. A compensation scheme will be discussed and inverted parameters will be compared to ground truth. [Work supported by ONR.]

1pAOb7. Littoral and deep-seafloor sediment characterization from recent chirp sonar surveys. Altan Turgut, Raymond J. Soukup, Edward L. Kunz (Naval Res. Lab., Acoust. Div., Washington, DC 20375), and Warren T. Wood (Marine GeoSci. Division, MS 39529)

Sediment sound-speed and attenuation were estimated from the chirp sonar reflection data that were collected during recent surveys in the New

Jersey Shelf and northern Gulf of Mexico. Physical properties of the sediment were also estimated using the Biot–Stoll model outlined in [Schock, IEEE J. Ocean. Eng. **29**(4) (2004)]. In addition, independent measurements of sound-speed and attenuation were also conducted using acoustic probes and light-bulb implosions. Results from independent measurements were in agreement with those of chirp sonar data. Measured sound speed and attenuation values are typical of silty-sand sediments in the New Jersey Shelf and

silty-clayey sediments in the northern Gulf of Mexico. Finally, frequency-dependence of sound-speed and attenuation was estimated within a wide frequency band using the data from co-located light-bulb implosion (0.5–4 kHz), chirp-sonar, (2–12 kHz), and sediment acoustic-probe (5–120 kHz) measurements. Observed small frequency-dependence of sound-speed and linear frequency-dependence of attenuation are in agreement with those predicted by an extended Biot–Stoll model. [Work supported by ONR.]

3:10–3:20 Break

Invited Papers

3:20

1pAOB8. Techniques in coastal seismic oceanography: An example in the Adriatic Sea. Warren Wood (Naval Res. Lab., 1005 Balch Blvd, Stennis Space Ctr., MS, 39529), Richard Hobbs (Univ. of Durham, United Kingdom), Jeffrey Book (Stennis Space Ctr., MS 39529), and Sandro Carniel (Inst. of Marine Sci., Venice)

The rapidly developing field of seismic oceanography (SO) uses frequencies far lower (10–200 Hz) than traditional acoustic oceanography, and is not a measure of particulate scattering strength, but rather a direct, quantitative measure of vertical temperature gradient. The temperature gradient is typically a very weak signal (reflection coefficients of 0.001 or less) in the presence of higher amplitude coherent noise, such as the direct wave, and the reverberation of the ship noise (in shallow water). Towing the system faster than 4–5 kts to cover greater distances quickly increases streamer noise. Our objective to develop SO into a useful oceanographic tool is, therefore, a signal-to-noise problem, with mostly coherent noise. Using data acquired in the first coastal application of SO (ADRIASEISMIC), we show the magnitude of the noise sources and how they have been mitigated to result in quantitative (albeit band-limited) measures of temperature gradient from a few tens of meters below the sea surface to just meters above the seafloor. The profiles allow the detailed tracking of very small ocean features, among them warm thermohaline intrusions and dense, cold, bottom water masses, both in places only 10 m thick.

3:40

1pAOB9. Modeling backscatter from a series of sediment rough interfaces and mud inclusions by a normal incident chirp sonar. Dajun Tang and Brian Hefner (Appl. Phys. Lab, Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105)

A chirp sonar measures reflection and backscatter of normal incident sound from sediment interfaces and volume heterogeneity. Motivated by using such chirp sonar data to invert for geoacoustic parameters, a forward model has been developed and reported that uses an exact method on which practical models can be based. Further development of the model is presented to (1) investigate spatial resolution of rough interface scatter for given bandwidth and (2) to include the scattering from volume heterogeneity such as mud inclusions.

4:00

1pAOB10. Acoustic imaging and structural acoustic analysis of scattering from buried targets at above-critical grazing angles. Zachary J. Waters (Physical Acoust. Branch - Code 7130, Naval Res. Lab., 4555 Overlook Ave., Washington, DC, 20375)

Laboratory experiments are conducted in order to examine above-critical angle source configurations for the detection and identification of objects fully buried in water-saturated sediments. A stationary broadband spherical source (3–40 kHz) insonifies realistic unexploded ordnance (UXO), as well as objects representing both natural and man-made clutter, at several aspects from above the critical angle. Bistatic returns, received on a two-dimensional synthetic array, are processed to generate volumetric acoustic images of the objects buried in a variety of orientations. Physical acoustics based interpretations are applied in order to identify features attributed to geometric and elastic scattering processes, as well as the interaction of scattered returns with the water-sediment interface. The symmetry of images attributed to cylindrically shaped UXO is suggested as a potential feature for the discrimination of these objects from clutter. The complementary role of volumetric imaging relative to feature-based identification from this same data set is discussed. [Work Supported by SERDP and ONR.]

4:20

1pAOB11. Acoustic imaging and structural acoustic analysis of laboratory measurements of scattering from buried targets above critical grazing angles. Harry J. Simpson, Zachary J. Waters, Brian H. Houston (Physical Acoust. Branch, Naval Res. Lab., 4555 Overlook Ave., SW, Washington, DC 20375, Harry.simpson@nrl.navy.mil), Kyrie K. Jig, Roger R. Volk, Timothy J. Yoder (Sotera Defense Solutions, Crofton, MD 20815), and Joseph A. Bucaro (Excet, Inc., Springfield, VA 22151)

A broadband (3–40 kHz) compact range measurement technique has been developed to obtain the acoustic scattering from buried unexploded ordnance and objects simulating natural and man-made clutter. The targets—two 5 in. rockets with 0, 30, and 60 deg pitch angles, a large rock, and cinder blocks with 0 and 45 deg roll—are buried 10 cm beneath the surface of a water-saturated sandy bottom with a mean grain size of 240 μm . A 2D synthetic array is generated at a height of 20 cm above the sediment–water interface with an element spacing of 3 cm (25 kHz Nyquist). Waveforms collected on the synthetic array are processed to extract the structural acoustic response of the buried targets. A Relevance Vector Machine algorithm applied to the scattered data for target identification, which shows that the target features separate even as the receiver array size is considerably decreased. Similar results are presented for numerical simulations of the bistatic returns for the buried 5 in. rocket and a rock of comparable size. [Work supported by ONR and SERDP.]

4:35

1pAOB12. Buried object imaging using reflection tomography. Altan Turgut (Naval Res. Lab., Acoust. Div., Washington, DC 20375)

A recent pioneering study of Steven Schock provided high-quality imaging of buried objects using the buried object sensing sonar (BOSS) system in a towed or AUV-mounted configuration [Schock, Proc. IEEE Oceans, 2005]. This paper numerically investigates the performance of compressive

sensing (CS) and standard backprojection methods for imaging multiple buried objects using a sonar system similar to the BOSS. Synthetic data are generated using a 3-D pseudo-spectral model for different sediment types and geometries including synthetic aperture sonar. As compared to the standard backprojection methods, the CS-based reflection tomography provided sharper images of buried objects using smaller data sets. Based on the CS performance, several improvements on the BOSS system and data collection schemes are also presented. [Work supported by ONR.]

4:50

1pAOB13. Delay, scale, and sum migration for planar layer imaging. Sean K. Lehman (Lawrence Livermore, Natl. Lab., 7000 East Ave., Livermore, CA 94550)

Wave-based remote sensing and imaging provide methods for investigating structures or objects with minimal or no contact. Delay, scale, and sum migration is one such method (in some circles this is known as “beam forming” or “migration” but must not be confused with beam forming for target location or geophysical migration). Migration assumes coherently scattered fields will sum constructively at a scattering target and destructively elsewhere. There is an additional assumption that multiple scattering can be neglected but this can be relaxed as the forward model sophistication is increased. This presentation summarizes the forward scattering model and derived inverse imaging algorithm as applied to a two planar layer medium. The measurement system operates in a broadband reflection mode in the one layer with the goal of imaging the second layer. Examples are presented using real data in (1) an ultrasonic experiment to measure a flaw in an aluminum/copper multilayer and (2) a ground penetrating radar in an air/sand environment. The examples provide a proof-of-principle using real data and may be scaled to other wavelengths and environments. [LLNL-ABS-485305 This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.]

MONDAY AFTERNOON, 31 OCTOBER 2011

TOWNE, 2:00 TO 4:45 P.M.

Session 1pMUa

Musical Acoustics: Acoustics of Mouth Organs

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

Chair's Introduction—2:00

Invited Papers

2:05

1pMUa1. Eastern and Western free reed mouth organs: Acoustics and history. James P. Cottingham (Phys. Dept., Coe College, 1220 First Ave., NE, Cedar Rapids, IA 52402)

The Asian mouth blown free reed instruments are of ancient origin and typically employ a free reed strongly coupled to a pipe resonator. In these reed-pipes, the same reed often operates on both directions of airflow and behaves as a blown-open or outward striking reed, with playing frequency above both the resonant frequency of the pipe and the natural frequency of the reed. Although the Asian instruments were known in Europe when the Western free reed family originated there about 200 yr ago, the Western free reed instruments use a different mechanism. In these instruments, the reed tongue is offset from the opening in the frame, permitting operation on only one direction of air flow. Pipe resonators are not required and generally not used. These free reeds behave as blown-closed or inward striking reeds, with playing frequency below the natural frequency of the reed. This paper presents some episodes in the history of the Eastern and Western free reed instruments and a summary of the important acoustical properties of each.

2:25

1pMUa2. Chromatical playing on diatonic harmonica: From physical modeling to sound synthesis. Laurent Millot (Inst. d'esthétique, des arts et technologies UMR 8153, CNRS, Univ. Paris 1, ENS Louis-Lumière, 7 allée du Promontoire, BP 22, F-93161 Noisy-le-Grand Cedex, France)

To understand chromatical playing on a diatonic harmonica one must consider both the instrument and the musician. For each of the harmonica holes, two reeds share a single reed chamber and, theoretically, there is one reed for each direction of airflow (blown or drawn note) while both reeds practically contribute to escaping airflow. The airflow model must take into account all 3D local airflow free jets passing between the plate and the local bent portion of the studied reed to give access to realistic numerical simulations. But to explain bends and overnotes, the vocal tract of the musician must be included and adapted. The vocal tract model must include at least a pressure excitation in the back cavity, the palatal constriction, the front cavity and a mix between lips channel and harmonica chamber. And, the physics involved in the whole model is acoustical nonlinear fluid mechanics rather than acoustical wave propagation. All relevant physical phenomena will be described and illustrated, sound synthesis given to listen. Moreover, a description of the time-variation of the vocal tract model will be proposed for ones thinking about real-time sound synthesis.

2:45

1pMUa3. Alternative method to determine minimal load for reeds within an acoustical flow. Laurent Millot (Inst. d'esthétique, des arts et technologies UMR 8153, CNRS, Univ. Paris 1, ENS Louis-Lumière, 7 allée du Promontoire, BP 22, F-93161 Noisy-le-Grand Cedex, France)

To understand (free) reed(s) oscillations, a minimal acoustical load must be introduced between the excitation and the reed(s). Classically, the model for this load is either an acoustic admittance/impedance or a reflexion function. But with an existing acoustical flow as found within some experiments, the whole model should better use nonlinear acoustical flow descriptions. Considering electrofluid analogies to model local behavior of either incompressible or compressible elements, an iterative building of the acoustic load can be derived from which, for each studied load, a pure recursive linear filtering of the excitation can be found. With a time-independent excitation, the acoustic load can create instabilities or not according to the filter poles. Using this method one can find again the minimal load to explain oscillations of either single blown-closed or blown-open reed but also the minimal description of the vocal tract needed for chromatical playing on diatonic harmonica. It is also possible to easily derive the numerical approximation of the acoustic load and reed(s) equations using a single numerical scheme, if a highly sufficient sampling frequency is chosen (maybe greater than 44.1 or 48 kHz), to perform numerical simulations of the studied acoustical problem.

3:05–3:15 Break

3:15

1pMUa4. Aeroelastic analysis of a closing reed of the mouth organ (harmonica). James F. Antaki, Jeongho Kim, Abhinav Singhal (Dept. of Biomedical Eng., Carnegie Mellon Univ., 700 Technol. Dr. Pittsburgh, PA 15219, antaki@cmu.edu), Greg Burgreen (Computational Simulation and Design Ctr., MS State Univ.), and Fangjun Shu (Mech. & Aerosp. Eng., New Mexico State Univ.)

A 3-D numerical simulation of the fluid-structure-interaction of a vibrating free reed was conducted representing an isolated closing reed of the mouth organ. Air flow was considered Newtonian and compressible. The reed was considered mildly viscoelastic. Both large eddy and SST turbulent models were evaluated. Independent variables included upstream resonant chamber dimensions (length and cross section), lateral reed clearance, and offset gap. Particular attention was given to the influence of the initial pressure impulse upon initiation of self sustained oscillations. Numerical results were corroborated by flow visualization within a transparent replica of an isolated harmonica cell using high speed videography (3 000 frames/s) with smoke tracer. These results provide guidelines for improving the responsiveness of the initial transient attack and avoidance of the phenomenon known as "reed choking."

3:35

1pMUa5. Contemporary composition for the traditional Lao free-reed mouth organ khaen. Christopher Adler (Music Dept., Univ. of San Diego, 5998 Alcalá Park, San Diego, CA 92110, cadler@sandiego.edu)

The khaen is a bamboo free-reed mouth organ prominent among people of Lao ethnicity in Laos and Northeast Thailand and is likely related to ancestors of other Asian free-reed instruments as well as to Western free-reed instruments. New Musical Geographies is an ongoing project by composer/performer Christopher Adler to promote the khaen as a concert instrument in the Western contemporary concert music tradition by encouraging the composition of new works for the instrument. To date, the project includes 17 solo and ensemble compositions by six composers. The diverse compositional strategies of these composers and their relationships to traditional performance techniques and musical structures will be discussed. The presentation will include the performance of selected compositions and examples of traditional-style improvisations.

3:55

1pMUa6. Chromatic playing on a diatonic harmonica. Howard Levy (P.O. Box 5010, Evanston, IL 60204, harpkeys@hotmail.com)

The purpose of my demonstration is to show how a diatonic harmonica player can get all the chromatic pitches on an instrument not intentionally designed for this purpose. I will recount my participation in the research done by Henry Bahnson and James Antaki in the 1990s that led to a more complete understanding of this phenomenon, and will describe my discovery of overblows and overdraws which enable a diatonic harmonica player to get the so-called missing notes, not obtainable by conventional draw and blow bending techniques. I will demonstrate conventional note-bending techniques as well, and play samples of my playing in different styles making use of these techniques—Blues, Jazz, Ethnic music, Classical, etc., on the ten hole diatonic harmonica.

4:15

1pMUa7. Wall vibrations in air-driven free reed bamboo pipes. Miles Faaborg and James P. Cottingham (Phys. Dept., Coe College, 1220 First Ave., NE, Cedar Rapids, IA 52402, jmfaaborg@coe.edu)

In previous investigations of wall vibrations in bamboo pipes from Asian free reed mouth organs, modal frequencies and mode shapes of a number of pipes were measured. Measurements of pipe input impedance were made, some of which suggested possible changes occurring as a result of damping the pipe vibrations. [Cottingham, J. Acoust. Soc. Am. **114**, 2348 (2010)]. The goal of this current work is to study the vibration of the pipe walls for the mechanically blown reed-pipe combination. This was done for undamped pipes and pipes heavily damped with sand or other damping material. Measurements of the internal sound field for both damped and undamped pipes were made as well as measurements of pipe impedance. Effects of the damping of wall vibrations on the radiated sound and the sounding frequency were also explored. [Work partially supported by National Science Foundation REU Grant PHY-1004860.]

4:30

1pMUa8. The diatonic harmonica, pipe resonators, and the siren. Casey N. Brock (Austin Peay State Univ., Clarksville, TN 37044, casey.brock@hotmail.com) and James P. Cottingham (Phys. Dept., Coe College, 1220 First Ave. NE, Cedar Rapids, IA 52402)

A number of measurements of reed motion and sound field have been made on a diatonic harmonica mounted on a fixed volume wind chamber. These include variation of sounding frequency with blowing pressure and the degree to which the sounding frequency and sound spectrum can be altered by attaching external pipe resonators. Differences were observed between the behavior of blow and draw reeds as well as the dependence of the results on whether the secondary reed in the reed chamber is allowed to vibrate. As noted by Helmholtz, at a simple level of analysis, the sound production of a free reed is similar to that of a siren, in both cases involving an air stream that is periodically interrupted. Our current results are compared with the results of measurements made in an earlier study of a siren in similar experimental configurations. [Work partially supported by National Science Foundation REU Grant PHY-1004860.]

1p MON. PM

MONDAY AFTERNOON, 31 OCTOBER 2011

GARDEN SALON 1, 5:00 TO 6:00 P.M.

Session 1pMUB**Musical Acoustics: Mouth Organ Concert**

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

Chair's Introduction—5:00

Following the lecture session on Acoustics of Mouth Organs, a concert will be held featuring Howard Levy on the harmonica and Christopher Adler on the khaen.

MONDAY AFTERNOON, 31 OCTOBER 2011

SUNSET, 1:00 TO 2:05 P.M.

Session 1pSAa**Structural Acoustics and Vibration: Structural Acoustics and Vibration Distinguished Lecture**

Dean E. Capone, Chair
Applied Research Lab., Pennsylvania State Univ., State College, PA 16804

Chair's Introduction—1:00**Invited Paper**

1:05

1pSAa1. Modeling of vibration, sound, and stresses using the virtual source approach. Goran Pavic (Vib. and Acoust. Lab., Nat. Inst. of Appl. Sci. 20 Ave., A. Einstien, 69621 Villeurbanne, France, goran.pavic@insa-lyon.fr)

Analytical solutions of acoustical, vibration, or stress problems are available only for some simple structural systems, e.g., a rectangular simply supported plate or a parallelepipedic cavity. An usual way of finding a solution where complex systems are concerned is to apply field discretization in conjunction with some numerical methods such as FE or BE. Yet the use of analytical models is desirable for its simplicity and better physical understanding of phenomena concerned. On top of this, analytical models give the possibility of

assessing quantities like energy flow which are linked to higher spatial derivatives, the latter being difficult to model numerically. The method of virtual sources enables one to obtain analytical solutions of systems of rather simple but non-trivial geometry. A key advantage of the method is the full control over the computation error. The method consists in applying a layer of virtual sources to a simple mother system of known analytical solution. These sources are adjusted in such a way as to produce particular boundary conditions on a target part of the mother system. The target part can be given a complex geometry which cannot be directly treated analytically. The paper will be accompanied by a number of examples which illustrate the approach.

MONDAY AFTERNOON, 31 OCTOBER 2011

SUNSET, 2:20 TO 5:35 P.M.

Session 1pSab

Structural Acoustics and Vibration: Assorted Topics on Structural Acoustics and Vibration

James E. Phillips, Chair

Wilson Ihrig and Associates, 6001 Shellmound St., Emeryville, CA 94608

Chair's Introduction—2:20

Contributed Papers

2:25

1pSab1. Aperture extension for near-field acoustical holography applied to jet noise. Alan T. Wall, Kent L. Gee, David W. Krueger, Tracianne B. Neilsen (Dept. of Phys. and Astronomy, Brigham Young Univ., N283 ESC, Provo, UT 84602, alantwall@gmail.com), and Michael M. James (Blue Ridge Res. and Consulting, Asheville, NC 28801)

Near-field acoustical holography (NAH) techniques are used to investigate noise source characteristics of high-power jets on military aircraft. Sound field reconstruction of large sources, measured with an aperture of limited size, may generally be performed with the use of patch NAH methods. Patch methods, such as statistically optimized near-field acoustical holography (SONAH), help to mitigate the effects of a truncated measurement aperture by avoiding the use of the spatial discrete Fourier transform operation. However, the lack of information outside the measurement aperture may lead to other errors, particularly when large propagation distances are required. Some missing data must be recovered to propagate beyond the immediate measurement region. Numerical aperture extension methods, in conjunction with SONAH, are employed to characterize high-power jet noise sound fields. These methods include complex interpolation and extension, analytic continuation, and in-plane holographic projection. [Work supported by Air Force SBIR.]

2:40

1pSab2. Explicit modeling of cubic stiffness in large amplitude dynamic response of metal plate under impingement of solid rocket motor plume. Hvard Vold, Paul Blelloch, Allison Hutchings, and Nate Yoder (11995 El Camino Real, Ste. 200, San Diego, CA 92130, havard.vold@ata-e.com)

Determining the damping characteristics of launch vehicle structures has risen to a high priority issue, since dynamic response in modeling and simulations is directly related to assumed damping. An experiment was conducted wherein an instrumented flat plate was excited by hydrodynamic fringes of the plume of a solid rocket motor. Estimation of damping was performed by variations of maximum entropy parametric spectrum estimation. Equivalent damping ratios of 5% were observed, even though the damping was observed to be amplitude dependent, with lower damping ratios associated with lower amplitudes. Analytic simulations, with fixed damping ratios and large displacement and rotation geometric effects, showed similar characteristics to the measured test responses. The hypothesis was formed that the structure is dominated by cubic stiffness effects under the observed impingement conditions, and that the damping actually

remains constant, effectively limiting the dynamic response and giving the appearance of an increased damping ratio. Since one can estimate velocity and displacement time histories by filtering measured acceleration time histories, a time domain maximum entropy model can be formulated. The cubic stiffness terms are linear parameters and all nonlinear terms being computed from the measured kinematic quantities. The estimated results will be compared with analytic simulations.

2:55

1pSab3. Shock transmission and eigenvalue veering within a coupled system. Kiran Vijayan and Jim Woodhouse (Dept. of engineering, Univ. of Cambridge, Cambridge, CB2 1PZ, United Kingdom, kv247@cam.ac.uk)

The operation of dynamical systems in harsh environments requires continuous monitoring. Internal sensors may be used to monitor the conditions in real time. A typical example is the sensor and electronic components used in space structures which, especially during launch, are subject to huge g force. The paper will present an experimental and theoretical study on a simplified model used to analyze the possible cause of high acceleration on the enclosed sensors and equipments due to impulsive loading. The model system consists of two beams coupled using compliant connections. An impulse hammer excites one beam, and vibrations are transmitted to the indirectly driven beam. A theoretical model is developed using a Rayleigh-Ritz approach and validated using experimental results in both the frequency and time domains. Monto Carlo simulation was done with random masses positioned on the indirectly driven beam to determine the worst-case conditions for maximum peak acceleration. Highest acceleration levels were found when mode matching in the two beams led to veering behavior in the coupled modes. The results suggest guidelines for the detailed design of internal components of a structure exposed to shock loading from its environment. [The authors thank Schlumberger Cambridge Research for financial support.]

3:10

1pSab4. Experiences in performing a high-intensity, direct-field acoustic test on a contamination sensitive system. Eric C. Stasiunas, Vit Babuska, Troy J. Skousen, and David J. Gurule (Eng. Sci. R&D, Sandia Natl. Labs., P.O. Box 5800, MS-0557, Albuquerque, NM 87185, ecstasi@sandia.gov)

A direct-field acoustic test (DFAT) was performed on a Sandia system in order to verify survival due to an acoustic environment of 146.7 dB OASPL. The DFAT technique performed by surrounding a test article with a wall of speakers and controlling the acoustic input with a closed-loop control system was chosen as the test method in order to meet a

critical schedule. In choosing this test method, other challenges became apparent, such as how to obtain the high-intensity acoustic levels and what occurs to that environment inside the bagged frame constructed to maintain a contamination-free system. In addition, the vast amounts of data measured during a single test necessitated a way for the test director to quickly visualize the acoustic environment, saving time and provide insight for input adjustments if necessary. Finally, even though the specified acoustic environment was successfully obtained, the results illustrated some drawbacks of the current DFAT method. This paper will detail the DFAT setup used to obtain the test specification, the effects of the contamination frame on the acoustic environment, the quick-look data program created for visual analysis of the acoustic field, and ideas for performing more diffuse DFAT tests in the future.

3:25

1pSAb5. The effect of ribbing and pressurization on the vibro-acoustic response of a turbulent boundary layer excited panel. Micah R. Shepherd and Stephen A. Hambric (Appl. Res. Lab., The Penn State Univ., P.O. Box 30, State College, PA 16804)

One of the largest contributors to interior aircraft noise is the direct radiation from the wall panels excited by turbulent boundary layer (TBL) flows. The wall panels are designed with ribbing to increase their stiffness and strength while maintaining a relatively low weight. The effect of the ribbing on the vibro-acoustic response is examined for TBL flow excitation. Normal modes of a typical aluminum aircraft panel are computed and compared with and without the ribs. Wavenumber transforms of the mode shapes reveal increased sensitivity of the ribbed panel to high wavenumber excitation. TBL forcing functions are then converted into modal space and used to compute the radiated sound power of each panel. The increase in radiated sound power will be discussed in terms of wavenumber sensitivity. A preload due to pressurization is then applied to the ribbed panel and the modes, wavenumber spectrum and radiated sound power are recomputed. The pressurization causes a significant change in the modal content and subsequently the wavenumber spectrum and radiated power. The general effect of preload will be discussed in the context of interior aircraft noise predictions.

3:40

1pSAb6. Lab vibration complaints due to secondary or questionable indicators. Jack B. Evans and Chad N. Himmel (JEAcoust., 1705 W Koenig Ln, Austin, TX 78756, Evans@JEAcoust.com)

Researchers complained about lab vibration in a new multi-floor academic laboratory building after observing surface ripples in water glasses on lab shelves. Structural vibration and low frequency noise can effect sensitive laboratory equipment, degrade experimental specimens and reduce staff efficiency and productivity. Investigatory observations and measurements were undertaken to determine vibration and noise conditions and develop a plan of mitigation. Permissible 1/3 octave Vibration Criteria (VC) and full-octave background noise Room Criteria (RC), including maximum limits for low frequency noise, had been used for building design. Central plant equipment, including pumps and compressors are on ground level. The facility is served by remote campus chillers. The building air handlers, exhaust fans, and boilers are in a penthouse mechanical equipment room and on roof. Structure borne vibration and airborne noise may be transmitted to laboratory spaces via building columns and beams, in pipes and ducts and through vertical duct and pipe shafts. Floor vibration and airborne sound spectra were measured during normal business hours (while the facility was occupied) at various locations for comparison with vibration and noise criteria. Results will be graphically shown on charts. Mitigation measures implemented by the facility management will be enumerated with subjectively determine results.

3:55–4:05 Break

4:05

1pSAb7. Vibrational and acoustical response of a railroad bridge with vehicle loading. R. Daniel Costley, Henry Diaz-Alvarez, and Mihan H. McKenna (U.S. Army Engineer Res. and Development Ctr., Geotechnical & Structures Lab., 3903 Halls Ferry Rd., Vicksburg, MS 39180, dan.costley@usace.army.mil)

A finite element model has been developed for a Pratt truss railroad bridge located at Ft. Leonard Wood, MO. This model was used to investigate the

vibration responses of the bridge under vehicle loading. Modeling results have been obtained for a single axle with two wheels traversing the bridge at different speeds. Superposition of multiple axles have been used to represent various combinations of locomotives and flatcars transiting the bridge. The analysis includes examining the vibrational response of the bridge. The output of the vibration response is used as an input to an acoustic FE model to determine the vibrational modes that radiate infrasound. The vibration and acoustic models of the railroad bridge will be reviewed and results from the analysis will be presented. Experimental results will also be presented.

4:20

1pSAb8. Effective control of machinery noise on offshore platforms. Arindam Ghosh (KBR, 601 Jefferson, Houston, TX 77002, arindam.ghosh@kbr.com)

Offshore noise control must consider operational noise levels in the Topsides work areas from the perspective of hearing conservation. At the same time, for human comfort, it must consider both direct and structure-borne noise transmission from the Topsides sources to the occupied spaces. This paper will summarize design stage case studies for controlling centrifugal compressor and water injection pump noise integrating commercially available outdoor and indoor noise modeling packages and statistical energy analysis software. Practicality and economics of achieving the specified noise limits will be demonstrated based on cost effectiveness and noise reduction capacity of mitigation measures such as acoustic insulation, acoustic blankets, in-line silencers, enclosures, anti vibration mounts, and damping cassettes. For centrifugal compressor noise control, controlling the piping radiated noise by acoustical insulation provides the greatest benefit. For water injection pump noise control, controlling the base plate radiated noise through viscoelastic damping proves most effective. Economic and technical barriers to effective employment of the advanced analysis tools to the field of offshore noise control will be discussed.

4:35

1pSAb9. Analytical vibration model for beam reinforced plate. Alexandre Sarda (Dept. of Mech. Eng., Centro Politécnico, P.O. Box 19011, Curitiba, PR 81531990, Brazil, pescador@ufpr.br)

Beam reinforced plates are typical components of offshore structures, as used in oil prospecting and production. The typical problem associated with this type of structure is the noise and vibration generated by machines and transmitted through the low damped structure. This vibration can propagate to the accommodation area and generate noise, which can generate stress to the crew. This work leads to develop deterministic models and solutions to be used on vibration levels estimation to beam reinforced plates. These models are used in several configurations, as an example L or T joined plates. The obtained results are then compared with finite element model for solution validating. This model will be used for calculating the coupling loss factors to be used in an statistical energy analysis.

4:50

1pSAb10. Energy scattering in weakly non-linear systems. Graham Spelman, Jim Woodhouse, and Robin Langley (Dept. of Eng., Univ. of Cambridge, Trumpington St., Cambridge CB2 1PZ, United Kingdom)

The Chinese Tam-Tam exhibits non-linear behavior in its vibro-acoustic response. The frequency content of the response during free, unforced vibration smoothly changes, with energy being progressively smeared out over a greater bandwidth with time. This is used as a motivating case for the general study of the phenomenon of energy cascading through weak nonlinearity. Numerical models based upon the Fermi-Pasta-Ulam system of non-linearly coupled oscillators, modified with the addition of damping, have been developed. These were used to study the response of ensembles of systems with randomized natural frequencies. Results from simulations will be presented here. For un-damped systems, individual ensemble members exhibit cyclical energy exchange between linear modes, but the ensemble average displays a steady state. For the ensemble response of damped systems, lightly damped modes can exhibit an effective damping which is higher than predicated by linear theory. The presence of a non-linearity provides a path for energy flow to other modes, increasing the apparent damping spectrum at some frequencies and reducing it at others. The target of this work is a model revealing the governing parameters of a generic system of this type and leading to predictions of the ensemble response.

IpSAb11. The plane wave expansion method applied to thin plates. Ismael Oviedo-de-Julián (Facultad de Ciencias, Universidad Nacional Autónoma de México, México, D.F., México and Universidad Autónoma Metropolitana-Azcapotzalco), Rafael A. Méndez-Sánchez (Universidad Nacional Autónoma de México, 62210 Cuernavaca, Mexico), Betsabé Manzanera-Martínez (Universidad de Sonora, NAvojoa, México.), Felipe Ramos-Mendieta (Universidad de Sonora, Hermosillo, Sonora, Mexico), and Elsa Báez-Juárez (Universidad Autónoma Metropolitana-Cuajimalpa)

The plane wave expansion method refers to a computational technique in electromagnetics to solve Maxwell's equations. This method is popular in the photonic crystal community, because it is possible to obtain the band structure (dispersion-relation) of photonic crystals with specific forms. Since photonic crystals are periodic systems, the method expands all parameters crystal in Fourier series (plane waves). These expansions transform the wave equation in an eigenvalue equation. In this work, we will follow the line of previous investigations where the plane wave method was applied to the classical theory of thin plates. In particular the plane wave expansion method will be applied to the Mindlin equation. This equation describes the out-of-plane vibrations of thin plates in a better way—the classical theory of thin plates.

IpSAb12. Doorway states in elastic one dimensional systems. Rafael A. Méndez-Sánchez, Alfredo Díaz-de-Anda (Inst. de Ciencias Físicas, Univ. Nacional Autónoma de México, P.O. Box 48-3, 62251 Cuernavaca, Mor., Mexico, mendez@fis.unam.mx), Jorge Flores (Inst. de Física, Univ. Nacional Autónoma de México, México D. F., Mexico), Luis Gutiérrez (Inst. de Ciencias Físicas, Univ. Nacional Autónoma de México, Cuernavaca, Mor., Mexico), Guillermo Monsivais (Inst. de Física, Univ. Nacional Autónoma de México, México D. F., Mexico), and Alejandro Morales (Inst. de Ciencias Físicas, Univ. Nacional Autónoma de México, Cuernavaca, Mor., Mexico)

Whenever a state of a "distinct" and simple nature is immersed in a sea of states of a different, more complicated, structure a strength function phenomenon appears: the amplitude of the distinct state is spread over the complicated eigenstates with a Lorentzian-like shape. The distinct state acts as a doorway state whenever this state is coupled to the continuum and to the sea of complicated states, but the latter are coupled to the continuum only through the distinct state. We present numerical and experimental results for an elastic system which presents a doorway state and the temporal evolution of the phenomenon is measured directly for the first time. The delayed and stationary responses of the system are discussed.

MONDAY AFTERNOON, 31 OCTOBER 2011

ROYAL PALM 1/2, 1:00 TO 3:00 P.M.

Session 1pSP

Signal Processing in Acoustics: Underwater Acoustic Communications

Hee Chun Song, Cochair

Scripps Inst. of Oceanography, Univ. of California, San Diego, 8820 Shellback Way, La Jolla, CA 92093-0238

Caglar Yardim, Cochair

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

Contributed Papers

1:00

1pSP1. Sparse acoustic response function estimation with a mixture Gaussian model. Paul Gendron (Maritime Systems Div. SSC-Pacific, 53560 Hull St., San Diego, CA 92152)

Underwater acoustic response functions at high frequencies and large bandwidths exhibit significant spatio-temporal variability that depends greatly on volume, boundaries, and the source-receiver motion. Considered here is a mixture Gaussian assignment over Doppler, beam-angle, and channel bandwidth employed to describe the behavior of the sparse acoustic response function over received signal duration, aperture, and bandwidth. Accurate modeling of the dependence between the mixture components can be handled by considering dependence among neighboring indicator variables of the mixture assignment. This allows for a more accurate and adaptable description of the natural persistence that acoustic paths exhibit and improve channel estimation quality. This adaptive structure is applied to underwater M-ary spread spectrum acoustic communication transmissions during the MACE10 experiment of the coast of Martha's Vineyard at near 10 kHz of bandwidth and at ranges of 1 and 2 km. Posterior conditional expectations of the acoustic response are compared with least squares type estimates and performance is quantified in terms of the observed bit error rate (BER) as a function of received SNR. A BER = E-6 at rSNR = -16 dB for 12 element combining is demonstrated. [This work is supported by the Office of Naval Research and by NISE BAR.]

1:15

1pSP2. Multi-input multi-output multicarrier acoustic communications in shallow water. Taehyuk Kang, Heechun Song, and William Hodgkiss (Scripps Inst. of Oceanogr., 9500 Gilman Dr. La Jolla CA 92093-0238, tedkang@ucsd.edu)

Recently multi-carrier orthogonal frequency division multiplexing (OFDM) communications, popularly used in wireless channels, has been introduced in underwater acoustic channels with a large delay spread, as an alternative to the typical single carrier approaches. In this paper, we investigate multiple-input/multiple-output (MIMO) OFDM communications which can effectively increase the data rate in band-limited underwater channels. The performance of MIMO OFDM communications will be illustrated using the data collected from the KAM11 experiment conducted in shallow water, west of Kauai, Hawaii, which involved multiple transmit and receive arrays with different bandwidths, inter-element spacings, and apertures at various ranges between them up to 10 km.

1:30

1pSP3. Estimation of acoustic communication channel capacity of an ocean waveguide disturbed by surface waves. Thomas J. Hayward (Naval Res. Lab., Washington, DC 20375)

The ocean environment is known to present significant challenges to underwater acoustic communication, including noise-imposed bandwidth

constraints and large-scale temporal dispersion due to macro-multipath propagation. In addition, acoustic interaction with the rough, moving ocean surface degrades the spatial and temporal coherence of acoustic communication signals, thereby diminishing the achievable data rates. In this work, the effects of the ocean surface on acoustic communication channel capacity are examined in a computational study for a shallow-water waveguide bounded by an ocean surface disturbed by gravity and capillary waves. Surface wave spectra are derived from empirical models [Donelan and Pierson, *J. Geophys. Res.* **92**, 4971] and are used to construct realizations of the 2-D moving surface. Then, 2-D and 3-D propagation models are applied to derive the space-time correlation properties of the acoustic channel, from which stochastic channel models are constructed. The adequacy of $N \times 2$ -D propagation modeling for this construction is also assessed. The channel models are then used as a basis for the estimation of channel spectral efficiency (achievable data rate per unit of frequency increment). Extensions to estimates of channel capacity are then discussed. [Work supported by the Office of Naval Research.]

1:45

1pSP4. Time reversal communications in a time-varying sparse channel. Hee-Chun Song (MPL/SIO, La Jolla, CA)

Recently, time reversal (TR) communications has been extended to time-varying channels. The basic idea is to implement it on a block-by-block basis such that within each block the channel remains time-invariant and subsequently is updated using detected symbols (decision-directed mode). Using experimental data (12–20 kHz) collected in shallow water, this letter investigates three different block-based TR approaches: (1) without explicit phase tracking, (2) with phase tracking, and (3) exploiting channel sparsity. The TR approaches then are compared to a conventional adaptive multichannel equalizer. It is found that approach (3) generally provides the best performance and robustness.

2:00

1pSP5. High frequency multiple-input/multiple-output time reversal acoustic communication. Aijun Song and Mohsen Badiy (114 Robinson Hall, Univ. of Delaware, Newark, DE 19716)

Current acoustic communication technologies using a single transmitter can only provide limited data rates due to the narrow bandwidth available in the underwater acoustic channel. Significant data rate increases can be achieved through the use of multiple-input/multiple-output (MIMO) systems in the underwater environment. However, in addition to the time-varying inter-symbol interference (ISI), co-channel interference (CoI) occurs as a result of multiple data streams sharing the channel at the same time and at the same bandwidth. Removal of both the CoI and ISI is a challenging problem in the underwater channel. This is especially true for high frequency acoustic communication (greater than 10 kHz). In order to achieve high data rate, reliable communication, time reversal MIMO processors have been developed. In the receiver, both the time-varying ISI and the CoI are addressed. Field data from recent high frequency acoustic experiments in the Pacific Ocean are used to demonstrate the receiver performance. Environmental impacts on acoustic MIMO communication will also be shown. [Work supported by ONR Code 322OA.]

2:15

1pSP6. Code division multiple access based multiuser underwater acoustic cellular network. T. C. Yang (Code 7120, Naval Res. Lab., Washington, DC 20375)

A multiple-access underwater acoustic cellular network is considered in this paper using direct sequence spread spectrum techniques similar to the

code division multiple access cellular network in RF communications. To keep a reasonable data rate, in view of the limited bandwidth in an underwater (UW) channel, the length and, therefore, the number of orthogonal codes (the number of users) cannot be too large. At the same time, the orthogonality of the codes is severely degraded by the extended multipath arrivals in the UW channel. As a result, communication bit error rate becomes non-negligible when the interferer's signal energy (due to increasing number of users) becomes order of magnitudes higher than the desired signal [Yang *et al.* *JASA* **126**, 220–228 (2009)]. In this paper, techniques used in multiple-input-multiple-output communications are applied to underwater cellular network for simultaneous communications between the users and the base station, taking advantages of the (rich) spatial degrees of freedom of the UW channel. Simulation and experimental results will be presented. [Work supported by the U.S. Office of Naval Research.]

2:30

1pSP7. Underwater acoustic communication channel simulation using parabolic equation. Aijun Song, Joseph Senne, Mohsen Badiy (114 Robinson Hall, Univ. of Delaware, Newark, DE 19716), and Kevin B. Smith (Graduate School of Eng. and Appl. Sci., Monterey, CA 93943)

High frequency acoustic communication (8–50 kHz) has attracted much attention recently. At these high frequencies, vaHigh frequency acoustic communication (8–50 kHz) has attracted much attention recently. At these high frequencies, various physical processes, including surface waves, sub-surface bubbles, and ocean volume fluctuations, can significantly affect the communication channel. While there is an on-going work, however, the research community is still lacking adequate numerical models that can provide realistic representations of both deterministic and stochastic channel properties in the dynamic ocean. Advancements in underwater acoustic communication technologies mainly rely on at-sea experiments, which are very costly. Our studies show that it is possible to simulate realistic communication channels through parabolic equation (PE) modeling. The Monterey-Miami PE model with an evolving sea surface has been used to generate time-varying impulse responses. Data from our recent experiments are used to evaluate the model in predicting acoustic communication performance. [Work supported by ONR Code 322OA.]

2:45

1pSP8. Resource allocation for orthogonal frequency division multiplexing (OFDM) underwater acoustic cooperative transmission with limited feedback. Xiaopeng Huang and Victor Lawrence (Dept. of Elec. and Comput. Eng., Stevens Inst. of Technol., Hoboken, NJ 07030)

In this paper, we first compare the difference between the wave cooperative (WC) protocol (designed for acoustic propagation) and amplify-forward (AF) protocol. In WC protocol, the relay nodes will transmit the received signal from the transmitter to the destination immediately (one time slot), in order to overcome the low transmission data rate problem in acoustic communication systems. Then we will propose the closed-form expression of the WC protocol with single relay. We will adopt the underwater acoustic (UWA) Rayleigh fading channel model and ambient noise in this cooperative transmission system. We propose capacity criterion based power allocation for UWA cooperative transmission (WC model) with the total transmitted power constraint, achieved under different levels of quantized CSI feedback using Lloyd algorithm. Meanwhile, limited feedback general procedure and Lloyd algorithm based codebook design will be presented. Simulation results will compare the system capacity with different bits of feedback, perfect feedback and non-feedback. In addition, the effect of relay locations on the system performance and the convergence speed of the Lloyd algorithm will be explored in the results.

Session 1pUW

Underwater Acoustics: Boundary Scattering From the Ocean Bottom or Surface

Grant B. Deane, Chair

Marine Physical Lab., Univ. of California, San Diego, La Jolla, CA 92093-0238

Contributed Papers

1:15

1pUW1. Reflection and refraction of sound on smoothed boundaries. Nick Maltsev (1467 Leafree Cir, San Jose, CA 95131)

Classic problems of reflection and refraction of sound waves on the boundary of two liquid half spaces are reformulated for more complicated and more realistic case, when acoustical properties of media change smoothly. Refraction and reflection of plane, cylindrical and spherical waves on smoothed boundaries is discussed. The propagation of waves in Pekeris waveguide with smoothed boundaries is also formulated and solutions for the point source are discussed. New formulas for rays and modes are derived for both cases.

1:30

1pUW2. Importance of surface forward scattering on reverberation level. Eric I. Thorsos, Jie Yang, W. T. Elam, Frank S. Henyey, and Brian T. Hefner (Appl. Phys. Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, eit@apl.washington.edu)

Transport theory has been developed for modeling shallow water propagation at mid frequencies (1–10 kHz) where forward scattering from a rough sea surface is taken into account in a computationally efficient manner. The method is based on a decomposition of the field in terms of unperturbed modes, and forward scattering at the sea surface leads to mode coupling that is treated with perturbation theory. Transport theory has recently been extended to model shallow water reverberation, and the effect of forward scattering from the sea surface is found to be very important in accurately modeling the reverberation level under winter-like (nearly isovelocity) sound speed conditions. At a frequency of 3 kHz and a wind speed of 15 knots (7.7 m/s) with a fully developed sea, the reverberation level from sea surface scattering is found to be up to 20 dB greater than when a coherent reflection loss is used to account for the effect of surface roughness during the propagation out to and back from the primary backscatter source of reverberation. Examples illustrating the importance of sea surface forward scattering on reverberation level are shown. [Work supported by ONR Ocean Acoustics.]

1:45

1pUW3. Observation of ocean surface scattering in the deep ocean using a towed array. Stephen D. Lynch, Gerald L. D'Spain (Marine Phys. Lab., SIO, 291 Rosecrans, San Diego, CA 92106), Kevin D. Heaney (OASIS, Lexington, MA 02421), Arthur B. Baggeroer (MIT, Cambridge, MA 02139), Peter Worcester (SIO, La Jolla, CA, 92093), James Mercer (APL-UW, Seattle, WA, 98105), and James Murray (OASIS, Lexington, MA 02421)

Over the course of an experiment in the northern Philippine Sea in 2009, weather and sea surface conditions varied from calm and smooth to stormy and very rough. A ship with an acoustic source deployed at 15 and 60 m held station while a second ship towed Penn State's Five Octave Research Array (FORA) at 120 m depth in an arc, maintaining constant range at the first convergence zone. With the source and receivers so near the ocean surface and with zero closing speed, these events offer an opportunity to extract information about the acoustic waves' interaction with the temporally varying ocean surface. Additionally, the FORA was towed at various depths in a star pattern about the stationary source ship, and a vertical acoustic array was deployed

near the source ship. Using meteorological data and a model for ocean waves given weather conditions and fully developed seas, these events offer an opportunity to separate in the data-adaptive beamformer output the arrivals scattered and Doppler shifted by the rough ocean surface while accounting for motions of the receiver and acoustic interactions with the bottom.

2:00

1pUW4. Predicting surface scattering from surface elevation time series. Grant B. Deane (Code 0238, Scripps Inst. of Oceanogr., UCSD, La Jolla, CA 92093-0238, gdeane@ucsd.edu) and James C. Preisig (Woods Hole Oceanograph. Inst., Woods Hole, MA 02543)

Surface reverberation in mid-frequency bands (we are considering 3–15 kHz) can be an important determinant for the performance of underwater communications systems operating in surface scattering environments. At these frequencies and at relatively short ranges (order 10 water depths), gravity waves focus sound energy incident on the surface, creating intensifications, Doppler shifts and phase shifts in the reflected field, all of which impact the performance of underwater acoustic communications systems. Observations of the time-varying arrival intensity structure from an experiment conducted in the Martha's Vineyard Coastal Observatory will be presented along with model calculations made using the Kirchhoff approximation. The sensitivity of the reflected field to the distribution of energy in the surface wave field and short wavelength gravity waves will be discussed. [Work supported by the ONR Ocean Acoustics Program.]

2:15

1pUW5. Real time simulation of element level time series for active sonars in deep ocean environment. Sheida Danesh (Dept. of Mech. Eng., Ctr. for Ocean Eng., MIT, 77 Mass Ave., Bldg. 5-223, Cambridge, MA 02139, sdanesh@mit.edu)

The simulation of experiments in deep ocean environments is becoming increasingly important to researchers due to expensive and complex modern equipment. Accurate simulations allow for more efficient use of ship time. LAMSS (Laboratory for Autonomous Marine Sensing Systems) at MIT has developed an indispensable tool for simulating real time active sonar experiments using a combination of ray tracing software (Bellhop), MATLAB, and MOOS-IvP (Mission Oriented Operating Suite - Interval Programming). A new key component to this toolbox is a module that models surface reverberation. Experiments in deep ocean environments are subject to environmental effects, such as the scattering of acoustic ray bundles on the ocean boundary due to upward refraction. Therefore, modeling surface reverberation is essential in deep ocean simulations when identifying target signatures in real time through active sonar. The implementation of this model is intended to simulate deep ocean active sonar experiments more accurately, thus optimizing on site data collection and evaluation.

2:30

1pUW6. Three-dimensional surface scattering using a parabolic equation model. Kevin B. Smith (Dept. of Phys., Naval Postgrad. School, Monterey, CA 93943, kbsmith@nps.edu), Mohsen Badiy, and Joseph Senne (Univ. of Delaware, Newark, DE 19716)

Calculations of acoustic rough surface scattering have previously been performed by numerous researchers using parabolic equation models in two

dimensions. Approaches have varied from exact solutions that re-map the rough interface to the pressure release boundary condition through a generalized method of images, approximate methods based on a perturbation approach valid for small slopes, and extended domain approaches that define the rough surface as a boundary between water and air with an additional absorbing boundary above the rough surface. In this work, we examine extensions of these approaches to the three-dimensional propagation. It is shown that the exact solution based on a generalized method of images does not yield realizable expressions for implementation. The other approaches are relatively easily adapted to three-dimensions, and some simple test cases involving Bragg scatter are analyzed for accuracy. Implications for other rough surface scattering model studies are also discussed.

2:45

1pUW7. Energy conservation in the Kirchhoff approximation. Sumedh M. Joshi and Marcia J. Isakson (Appl. Res. Labs., Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758)

The scattering of sound from rough interfaces is frequently modeled using the Kirchhoff approximation. As has been shown by Lynch and Wagner [J. Acoust. Soc. Am. **47**(3)] and others, for the case of a pressure-release surface, the Kirchhoff approximation fails to conserve energy. In particular, Lynch and Wagner derive an analytical expression for the proportion of incident energy conserved for a surface with a Gaussian roughness spectrum. They demonstrate that energy is not conserved near normal incidence due to the failure of the Kirchhoff approximation to multiply scatter rays back into the upper half-space. In this work, a Monte Carlo technique is used to quantify the degree to which energy is not conserved in the three-dimensional Kirchhoff approximation; these results are compared with theoretical prediction of Lynch and Wagner for the Gaussian spectrum. A similar Monte Carlo analysis is undertaken for other roughness types. Finally, it is shown that the integral solution, a model that accounts for multiple scattering and shadowing, conserves energy in the pressure-release case. [Work supported by ONR, Ocean Acoustics.]

3:00

1pUW8. Crosscorrelation of broadband signals scattered by a random pressure-release surface. P. J. Welton (Appl. Res. Labs, Univ. of Texas at Austin, Austin, TX 78713)

An expression for the crosscorrelation of omnidirectional, broadband acoustic signals scattered by the sea surface is derived for both vertically separated and horizontally separated hydrophones using an integral equation approach in conjunction with the Fresnel phase approximation, and the specular point approximation, i.e., the approximation that most of the scattered energy comes from regions close to the specular point. The resulting expressions are simple and have an obvious physical interpretation. In the limit as the surface becomes perfectly smooth, the expressions reduce to the image solution, thus ensuring conservation of energy.

3:15–3:30 Break

3:30

1pUW9. Fast direct integral equation-based analysis for acoustic scattering using non-uniform grid accelerated matrix compression. Yaniv Brick and Amir Boag (School of Elec. Eng., Tel Aviv Univ., Tel Aviv 69978, Israel, yaniv.brick@gmail.com)

An approach for the fast direct solution of scattering problems via compression of boundary element method (BEM) matrices is presented. Such an approach is advantageous for large resonant problems where iterative solvers converge poorly, or if the solutions are sought for multiple directions of incidence, so that the computational cost becomes proportional to the number of desired solutions. The compression is achieved by revealing the ranks of interactions between source and observation subdomains via algebraic analysis of the source subdomains' interactions with coarse non-uniform grids (NGs) surrounding the observation subdomains and vice versa. The NG field representation, originally developed for acceleration of iterative solvers [Y. Brick and A. Boag, IEEE Trans. Ultrason. Ferroelectr. Freq. Control **57**, 262–273 (2010)], is used to facilitate the computation of interacting and non-interacting mode sets that serve as a basis for a subsequent transformation of the BEM matrix. Only a highly compressed system

linking the interacting modes is solved prior to the solution's extraction for the non-interacting ones. Further compression and acceleration of a multilevel scheme is suggested based on a "layered-localized" field representation via modes sorted according to their radiation, directivity, evanescence, and focusing properties, which are also computed using the NG approach.

3:45

1pUW10. Effects of random bottom bathymetry on temporal and spatial coherence in shallow water propagation. Jennifer Wylie, Felipe Lourenco, and Harry DeFerrari (Div. of Appl. Marine Phys., Univ. of Miami, 4600 Rickenbacker Cswy, Miami, FL 33149, jwylie@rsmas.miami.edu)

Fixed system measurements for three experimental shallow water sites reveal systematic dependence of temporal and spatial coherence of individual mode arrivals on frequency and mode number that cannot be fully explained with internal wave variability. Here random fluctuations in bottom bathymetry are introduced to propagation models. Mode structures are randomized and coherence times and lengths decrease with increasing amplitude of bathymetry fluctuations for the same internal wave variations. Distinct mode features blur as frequency of pulse signals increased. Mode coupling and eventually a smearing of continuous modes are observed with increasing frequency and magnitude of bathymetry variations. For low frequencies and bathymetry variations constrained a small fraction of a wavelength, the bottom appears flat and nearly perfect discrete modes are formed. Modes are reinforced by specular reflections all along the path of propagation. Coherence depends entirely on internal wave fluctuations. All mode arrivals have nearly the same coherence times. But modes break up as height of bathymetry fluctuations become comparable to acoustic wavelength. Then sensitivity to sound speed fluctuation increases and coherence is reduced. Two dimensional bathymetry fluctuations account for observation out to 10–20 km and three-dimensional effects become important at longer ranges.

4:00

1pUW11. Characterization and scattering measurements from rock seafloors using high-resolution synthetic aperture sonar. Derek R. Olson (Graduate Program in Acoust., The Penn State Univ., 201 Appl. Sci. Bldg., University Park, PA 16802, dro131@psu.edu) and Anthony P. Lyons (The Penn State Univ., State College, PA 16804-0030)

Automated target detection systems are known to perform poorly in shallow water environments having high levels of reverberation and strongly varying scattering, such as rock outcroppings. Prediction of the scattering statistics is difficult because scattering from rock seafloors is not well understood. There is a lack of characterization methods, scattering strength measurements, and accurate approximate models for such interfaces. This research aims to measure the scattering strength of rock seafloors using an uncalibrated synthetic aperture sonar (SAS). An effective calibration has been made using a seafloor with a known scattering response. Scattering strength measurements will be used in conjunction with local slope information provided by interferometric SAS to characterize the rough interface.

4:15

1pUW12. Angular dependence of high-frequency seafloor acoustic backscatter (200–400 kHz). Christian de Moustier (HLS Res., Inc., 3366 North Torrey Pines Court, Ste. 310, La Jolla, CA 92037 cpm@hlsresearch.com), Gorm Wendelboe (RESON, AS, Denmark), Eric Maillard (RESON, Inc., Goleta, CA 93117), and Barbara J. Kraft (Barrington, NH)

Acoustic backscatter measurements were made with a RESON 7125-V2 multifrequency, multibeam sonar at 50 kHz increments between 150 and 450 kHz. The sonar was hull-mounted on a vessel held in a four-point moor in 17 m of water depth. The resulting constrained ship motion provided thousands of independent samples of the angular dependence of seafloor acoustic backscatter for grazing angles ranging from 90 deg to about 25 deg, over a well defined seafloor patch. Focused beamforming at all frequencies yielded fore-aft beam footprints with nearly constant width across the swath. Calibrated results are presented at 200 and 400 kHz, and relative results at all other frequencies. [Work funded by ONR-Ocean Acoustics (Code 32).]

1pUW13. A study on subcritical penetration into rough seafloor. Linhui Peng, Gaokun Yu (Information College, Ocean University of China, 238 Songling Rd., Qingdao, PRC), and Jianhui Lu (Ocean Engineering College, Ocean University of China, Qingdao, PRC)

Bragg scattering from rough interface of seafloor is one of the main causes of subcritical penetration of sound into seafloor. In this paper, the mechanism of subcritical penetration into rough seafloor is analyzed by Bragg scattering from sinusoidal fluctuation surface, and the condition that subcritical penetration can be induced is discussed. Because the refraction angle of minus order Bragg scattering waves is always smaller than refraction angle of Snell's penetration wave, the subcritical penetration attributes to the minus order Bragg scattering waves which propagate as normal plane wave below the critical grazing angle. So, in order to obtain the subcritical penetration, the minus order Bragg scattering wave should be considered detailed. The first order perturbation approximation is used for rough surface scattering usually. In this paper the validity of first order perturbation approximation for rough surface scattering is also checked by comparing the first order Bragg scattering wave with high order Bragg scattering waves.

1pUW14. Estimating seafloor roughness using synthetic aperture sonar image statistics. Anthony P. Lyons (Appl. Res. Lab., Penn State Univ., State College, PA 16804, apl2@psu.edu) and Shawn F. Johnson (Johns Hopkins Univ., Laurel, MD 21043)

In this work, we present a model to predict the impact of intensity scaling caused by random seafloor roughness on SAS image speckle statistics and the possible use of this model to estimate roughness parameters, such as root-mean-square height and slope. The continuous variation in scattering strength produced by roughness (i.e., roughness-induced changes in seafloor slope) is treated as an intensity scaling on image speckle produced by the SAS imaging process. Changes in image statistics caused by roughness are quantified in terms of an effective K-distribution shape parameter. Comparisons between parameter estimates obtained from the scaling model and estimates obtained from high-resolution SAS data collected in experiments off of the Ligurian coast near La Spezia, Italy, are used to illustrate the efficacy of the model. [Work performed under ONR Grants N00014-10-1-0051, N00014-10-1-0047, and N00014-10-1-0151].

Payment of an additional registration fee is required to attend this lecture see page A22

MONDAY EVENING, 31 OCTOBER 2011

SUNRISE, 7:00 TO 9:00 P.M.

Session 1eID

Interdisciplinary: Tutorial Lecture on Acoustics of Green Buildings

Lily M. Wang, Chair

Architectural Engineering, Univ. of Nebraska, Lincoln, 1110 S. 67th St., Omaha, NE 68182-0681

Chair's Introduction—7:00

Invited Paper

7:05

1eID1. Acoustics of green buildings. Ralph T. Muehleisen (Illinois Inst. of Tech., Civil and Architectural Eng., 3201 S Dearborn, Rm. 228, Chicago, IL 60616, muehleisen@iit.edu)

As the world realizes the considerable environmental impacts of building construction and operation, a strong movement to create more sustainable buildings, i.e., "green" buildings has developed. While energy and resource use of green buildings is reduced and some indoor environmental conditions are improved, the acoustics of green buildings are often ignored and are frequently worse than in conventional buildings. In this tutorial presentation, the sustainable building movement is reviewed, the major design differences between green and conventional buildings are explained, and the impact of green design on acoustics is explored. There will be animations and auralizations to help attendees better understand acoustic impacts of green building design choices. Finally, lest ye think all is bad, the presentation will discuss solutions to the green building acoustic problem and present some of the positive impacts of green buildings can have on acoustics.