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 m^2 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 consistancy 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 Unv. 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 (Pontifícia 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 affects, 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 (Crt. 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

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.

1:25

1pAOb2. Steve Schock and the Narragansett Bay Project. Kenneth M. Walsh (K+M Eng. Ltd., 51 Bayberry Ln., Middletown, RI 02842, kwalsh4@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.

1:45

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.

2:05

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

2:25

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.

2:40

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.]

2:55

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 tradition 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 goeacoustic 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'esthé-tique, des arts et technologies UMR 8153, CNRS, Univ. Paris 1, ENS Louis-Lumiére, 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 allèe 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 Alcala 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.

Contributed Papers

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.]

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 Koening 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.

5:05

1pSAb11. 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 Manzanares-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.

5:20

1pSAb12. 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 Badiey (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 Badiey (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, subsurface 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 on smoothed boundaries. Nick Maltsev (1467 Leaftree 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 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 researches 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 Badiey, 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).]

4:30

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.

4:45

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.