Session 1aAB

Animal Bioacoustics and Psychological and Physiological Acoustics: Comparative Neurophysiology of the Auditory System I: Session in Honor of Albert Feng

Andrea Simmons, Cochair
Brown University, Box 1821, Providence, RI 02912

Peter M. Narins, Cochair
Integrative Biology & Physiology, UCLA, 621 Charles E. Young Dr. S., Los Angeles, CA 90095

Chair's Introduction—9:00

Invited Papers

9:10

1aAB1. Sexual communication in ultrasonic frogs *Odorrana tormota* involves acoustic and various visual signals. Albert S. Feng (Dept. Molec. & Integrative Physiol., Univ. of Illinois, 524 Burrill Hall, Urbana, IL 61801, fengatcu@gmail.com), Fang Zhang, Pan Chen, Juan Zhao, and Zhuqing Chen (College of Life Sci., Anhui Normal Univ., Wuhu, China)

Female concave eared torrent frogs are known to produce courtship calls to attract males; yet, like other anurans, they also display positive phonotaxis toward male's calls. Thus, it is unclear how amplexus is formed and which sex makes the mating decision. We investigated how males and females interact and communicate during the reproductive season and found that females emitted vocalizations during the gravid state only. In playback experiments in the wild, female's courtship calls elicited numerous males to respond. Males' vocal responses were range dependent and accompanied by staccato calls and phonotaxis toward (but short of reaching) the loudspeaker. In short range encounters, gravid females are highly selective, and males must wait for female's invitational signal(s) for amplexus. Only a select male showing prominent dominant male's postures received invitational signal(s), comprising a variety of visual signals (head bob, belly inflation, toe tapping, and eye blink) and an "admission" acoustic signal. Upon receiving one or more of these signals, the male immediately hopped on the female's back to form amplexus. Our studies revealed that intersexual communication in concave eared torrent frogs is complex, involving both acoustic and visual signaling.

9:30

1aAB2. The spatio-temporal analysis of male-male vocal interactions in chorusing frogs. Douglas L. Jones, Russell L. Jones (Elec. & Comput. Eng., Univ. of Illinois at Urbana-Champaign, Urbana, IL), and Rama Ratnam (Coordinated Sci. Lab., Univ. of Illinois at Urbana-Champaign, 1308 W. Main St., Urbana, IL 61801, ratnam@illinois.edu)

In some chorusing frog species, such as the green treefrog (*Hyla cinerea*), males can rapidly adjust call-timing with reference to neighbors and avoid acoustic interference while maintaining call-rate. The rules underlying vocal interactions are largely unknown, presumably being species-specific and governed by acoustic and physiological factors. Here, we use a microphone-array technique that can simultaneously localize callers and selectively extract the calls of each frog. This allows us to analyze vocal interactions between individual callers at high spatial and temporal resolutions. We show that green treefrogs can synchronize with one another and prefer to time their calls antiphonally that are on average exactly at one-third and two-thirds of the inter-call intervals of a focal neighbor. When antiphonal calling is not possible, call collision is tolerated even though a continuum of phase positions are available. The communication system in green treefrogs is thus "discrete" with callers capable of rapidly switching between the discrete phase-slots (0, 1/3, and 2/3) in response to changes in a neighbor's phase. Further, call collision increases and phase-locking decreases, with increasing inter-caller spacing. We conclude that the vocal communication system in green treefrogs is capable of robust maintenance of inter-caller timing so as to maintain chorus synchrony.

9:50

1aAB3. Instantaneous reproductive isolation in polyploid treefrogs: Mechanisms and consequences. H. C. Gerhardt (Div. Biol. Sci., Univ. of Missouri, 215 Tucker Hall, Univ. Missouri, Columbia, MO 65211, gerhardth@missouri.edu)

Speciation by polyploidy—duplication of chromosome sets—commonly occurs in plants and happened twice in the early evolutionary history of vertebrates. The gray treefrog (*Hyla versicolor*) is a recently evolved tetraploid species found in the eastern United States, where it often occurs with a cryptic diploid species (*Hyla chrysoscelis*). Assortative mating by ploidy is favored by selection because of triploid hybrid sterility and is based solely on selective phonotaxis of females to the species (ploidy)-specific calls of males. The tetraploid species has arisen multiple times independently; the calls and preferences of frogs in these lineages are nearly the same. Autotriploids of the diploid species created in the laboratory show parallel shifts in both the key call-properties of males and female preferences

in the direction of the wild-type tetraploid species. These shifts are probably caused by changes in cell size (larger in tetraploids) and number (fewer in tetraploids) rather than the difference in gene dosage. The magnitude of changes expected in autotetraploids would be sufficient for instant pre-mating isolation of diploids and recently derived tetraploids, hence promoting instantaneous speciation, which would then be reinforced by selection against the production of infertile hybrids.

10:10–10:25 Break

10:25

1aAB4. Frogs, thalamotectal neurons, and other things I learned about from Al Feng. Daniel Llano (Univ. of Illinois at Urbana-Champaign, 2355 Beckman Inst., 405 N. Mathews, Urbana, IL 61801, d-llano@illinois.edu)

In this presentation, I will discuss our work on the thalamotectal system, work inspired Al Feng and others working in the anuran thalamus. Descending projections from the thalamus to inferior colliculus are evolutionarily highly conserved. Despite the long history of work on this pathway in anurans and other species, the basic organization of the mammalian auditory thalamotectal pathway has yet to be characterized. We therefore studied the basic organizational properties of this pathway in mouse. We observed that a large proportion of cells from the medial and paralaminar divisions of the auditory thalamus project to the lateral cortex of the inferior colliculus. In addition, the vast majority of thalamotectal cells are negative for calcium binding proteins typically found in thalamocortical neurons. Double tracer injections revealed that thalamotectal cells do not branch to the amygdala or cortex. Finally, unlike thalamocortical cells, thalamotectal cells do not show typical T-type calcium channel-dependent bursting. These data suggest that the thalamocollicular pathway is neurochemically, neurophysiologically and anatomically distinct from primary auditory thalamic pathways, and bears resemblances to the anuran thalamotectal system. These results will be discussed in the context of Al Feng's ongoing influence on our laboratory (including unusual items left behind in the lab…).

10:45

1aAB5. Explorations of the unique anuran ear: The contributions of Al Feng. Andrea M. Simmons (Cognit., Linguist & Psychol. Sci., Brown Univ., Providence, RI 02912, Andrea_Simmons@brown.edu)

The anuran inner ear is unique among vertebrate ears in containing three organs for sound detection—the amphibian papilla, the basilar papilla, and the saccule (a mixed auditory/vestibular organ). Al's anatomical, physiological, and behavioral work in several different anuran species, from the American bullfrog to the Chinese torrent frog, has significantly furthered our understanding of the evolution and operation of this unusual ear. In this talk, I will review this species diversity in inner ear systems and I will further discuss how this diversity emerges over ontogenetic (metamorphic) development. Following up on Al's research into the post-metamorphic development of the amphibian and basilar papillae in bullfrogs, I will present anatomical data on the larval development of the inner ear in two anuran species, the bullfrog and the African clawed frog, which are adapted to live in different biomes as adults. These results focus attention on how differences in post-metamorphic habitats are reflected in developmental timetables of the maturation of the ear during tadpole life.

11:05

1aAB6. Re-visiting Al Feng's contributions toward understanding the peripheral basis of acoustic communication in frogs. William Shofner (Speech and Hearing Sci., Indiana Univ., 200 S. Jordan Ave., Bloomington, IN 47405, wshofner@indiana.edu)

Al has made substantial contributions toward understanding the peripheral auditory mechanisms underlying acoustic communication in frogs. Al was the first to demonstrate that the basilar papilla is innervated by high-frequency auditory nerve fibers, while the amphibian papilla gives rise to low- and mid-frequency fibers. As his graduate student, we subsequently showed that the tuning of these end organs changes during post-metamorphic development. Al developed a dorsal surgical approach to the auditory nerve, which allowed the coupling between the ears to be studied. He demonstrated that both the monaural directivity patterns and the coupling between ears are frequency dependent. In a follow-up study, we manipulated the coupling between ears and concluded that the frog's ear functions as a combination pressure/pressure gradient receiver. In this talk, I will re-visit the frequency-dependent crosstalk between the ears first described by Al in 1980. The crosstalk function is analyzed using an acoustic model of a tube with a side branch. This analysis shows the mouth cavity as the side branch is insufficient and yields a lowpass crosstalk function. Including the nares in parallel with the mouth cavity as a side branch yields a bandpass function for sound transmission that accounts for Al's empirical crosstalk data.

Session 1aAO

Acoustical Oceanography, Signal Processing in Acoustics, Underwater Acoustics, and Animal Bioacoustics: Acoustics of High Latitude Oceans I

Aaron Thode, Cochair
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John A. Colosi, Cochair
Department of Oceanography, Naval Postgraduate School, 833 Dyer Road, Monterey, CA 93943

Chair's Introduction—8:30

Invited Papers

8:35

1aAO1. The state of the Arctic Ocean, its variability and prediction—An overview. Wieslaw Maslowski (Oceanogr., Naval Postgrad. School, 833 Dyer Rd., Monterey, CA 93943, maslowsk@nps.edu)

The Arctic is a complex and integral part of the Earth system, influencing the global surface energy and moisture budgets, atmospheric and oceanic circulations, and geosphere-biosphere feedback. Some key influences are linked to the recent changes in the multi-year sea ice cover and the ocean. The ice cover is particularly important because it buffers air-sea heat fluxes and through ice-albedo feedback strongly influences Earth's absorption of solar radiation, especially by the ocean. Global warming has been most visibly manifested in the Arctic through a declining perennial sea ice cover, which has intensified during the late 1990s and the 2000s, resulting in record minima ice cover in 2007 and in 2012. This talk will provide an overview of the recent states and variability of the Arctic Ocean. We will focus on physical changes of potential relevance to the Arctic acoustics, including the past and present climatological changes, evolution of the upper ocean stratification and water masses, mesoscale processes, including eddies, mixing, coastal and boundary currents, and their linkages to the changing regime of the sea ice cover from multi-year to first-year sea ice. Finally, the latest advancements and outstanding challenges in modeling and prediction of arctic climate change will be discussed.

9:35

1aAO2. Airgun array sound measurements in the northeastern Chukchi Sea. David E. Hannay and Graham Warner (JASCO Appl. Sci., 2305-4464 Markham St., Victoria, BC V8Z 7X8, Canada, David.Hannay@jasco.com)

Underwater acoustic measurements were made during eight 2D/3D seismic surveys with large airgun arrays and nine shallow hazards surveys using small arrays (2–4 airguns) in the shallow (30–50 m) waters of the northeastern Chukchi Sea between 2006 and 2013. The acoustic measurements were made with calibrated seabed-deployed recorders to assess potential noise exposures to marine fauna. Data were acquired from directly under the airgun arrays to over 150 km distance. The seismic pulses contain signals above ambient noise between approximately 5 Hz and 15 kHz. Modal structure develops by about 1 km distance from the sources at frequencies between approximately 30 Hz and 600 Hz, but it is strongest from 100 Hz to 300 Hz. This ocean environment therefore acts as a frequency band-pass filter, selectively passing the intermediate sound frequencies to long distances. The modes are strongly dispersed, with low frequency components arriving up to 2 s later than the higher frequency sounds of the same mode. This causes received signals to have a down-swept spectral shape. We present sound level measurement results from all of the surveys and we discuss the frequency-dependent acoustic transmission loss in context with the modal propagation characteristics of this ocean environment.

10:00–10:15 Break

10:15

1aAO3. Unraveling the mystery of cold regime ecosystem variability in the Bering Sea through acoustics. Jennifer L. Miksis-Olds (Appl. Res. Lab., Penn State, PO Box 30, Mailstop 3510D, State College, PA 16804, jlm91@psu.edu) and Beth A. Stauffer (Biology, Univ. of Louisiana at Lafayette, Lafayette, LA)

The Bering Sea oscillates between warm and cold climatic regimes on 3–7 year cycles. During cold regimes, the bottom water layer, or cold pool, can remain below 2 °C the entire summer. When the cold pool forms, it acts as a cross-shelf barrier separating species of the outer shelf from others of the middle shelf and coastal areas. Backscatter recorded throughout the winter from echosounders on subsurface moorings in the southeastern Bering Sea provide a first glimpse on how dynamic the cold pool influence can be within cold regime years. The fall/winter scattering community composition was predictive of the structure during the first blooms the following

spring. Seasonal environmental conditions were also observed to play a dominant role in summer lower trophic level dynamics. Delayed ice retreat in the summer of the coldest years was associated with increased abundance of large zooplankton; yet relatively warmer years during the same cold climatic regime yielded a shift to smaller zooplankton scatterers during summer. Chlorophyll concentrations showed varying levels of correlation to zooplankton patterns, and sparse cruise-based data suggested differences in phytoplankton community composition likely influenced these relationships. Data on phytoplankton community structure remains a desperately needed dataset to fully understand the ecosystem dynamics.

10:40

1aAO4. Summer and winter whales in the Pacific Arctic. Kathleen Stafford (Appl. Phys. Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, stafford@apl.washington.edu)

Changes in sea ice phenology have been profound in the Pacific Arctic, where the seasonal open-water period has increased by ~1.5 months over the past 30 years. The greatest changes in the open water season have occurred in fall resulting in changes to the Arctic ecosystem, including increased primary productivity, changing food web structure, and opening of new habitat. In the "new normal" Arctic, sub-arctic "summer" whales (fin, humpback, and killer) are poised to inhabit new seasonally ice-free habitats in the Arctic. The spatial and seasonal occurrence of summer and "winter" (bowhead) whales over 5 years from September through December was examined by deploying hydrophones in Bering Strait and comparing acoustic occurrence of the species concomitant with decadal-scale changes in seasonal sea ice. Fin and humpback whale acoustic detections extended from summer to late autumn while killer whale detections were more sporadic. Inter-annual differences in acoustic detections appear to be driven by interannual differences in the environment. Bowhead whale detections generally began after the departure of the summer whales and continued through the winter. In a future with further seasonal sea ice reductions, however, increased competition for resources between sub-Arctic and Arctic species may arise to the detriment of winter whales.

11:05

1aAO5. Eight years of passive acoustic monitoring in the Alaskan Beaufort Sea: Lessons learned. Susanna B. Blackwell (Greeneridge Sci., Inc., 90 Arnold Pl., Ste. D, Santa Barbara, CA 93117, susanna@greeneridge.com), Christopher S. Nations (Western EcoSystems Technol., Cheyenne, WY), Aaron M. Thode (Scripps Inst. of Oceanogr., La Jolla, CA), and Katherine H. Kim (Greeneridge Sci., Inc., San Diego, CA)

Every year during open-water season in 2007–2014, up to 40 passive acoustic recorders with directional capability (DASARs) were deployed in the Beaufort Sea, as part of Shell's Marine Mammal Monitoring and Mitigation Program. The overarching goal of these deployments was to collect information on the effects of industrial operations, such as seismic exploration and drilling activities, on the behavior of bowhead whales during their fall migration. Recorders were placed on the continental shelf at depths of $<$55 m, offshore of the North Slope of Alaska, between Barter Island and Harrison Bay. Over the eight-year period, more than 3.1 million bowhead calls were localized. Concurrently, various types of industrial sounds were detected and quantified, such as airgun pulses or the tones produced by machinery. Analyses were then performed by matching—for each recorder—the number of calls localized with the amount of industrial sound detected. These analyses have shown that changes in calling behavior happen at low received levels of anthropogenic sound and lead to complex changes in calling behavior, that are governed by received sound levels, but also other factors, such as distance to the industrial activity or type of industrial sound. [Work sponsored by Shell Exploration and Production Company.]

Session 1aNS

Noise: Environmental and Community Noise

Eric L. Reuter, Chair
Reuter Associates, LLC, 10 Vaughan Mall, Suite 201A, Portsmouth, NH 03801

Contributed Papers

8:30

1aNS1. The initial development of a hybrid method for modeling outdoor sound propagation in urban areas. Matthew Kamrath, Julien Maillard, Philippe Jean, Dirk Van Maercke (Ctr. Scientifique et Technique du Bâtiment (CSTB), CSTB, 24 Rue Joseph Fourier, Saint-Martin-d'Hères 38400, France, matthew.kamrath@cstb.fr), and Judicaël Picaut (LUNAM Université, Ifsttar, AME, LAE, Bouguenais Cedex, France)

Accurately modeling urban outdoor sound propagation is a difficult problem. Using a frequency-domain or time-domain method is too expensive, and using an engineering, geometrical, or statistical method is too restrictive. For example, the ISO 9613-2, NMPB-Roads, and CNOSSOS-EU engineering methods only model diffraction for straight barriers. The Nord2000 and Harmonoise engineering methods can also model diffraction from wedge-shaped screens, but these modeling capabilities are still insufficient to model many potential noise mitigation solutions such as a gamma or T-shaped barrier. To extend the applicability of engineering methods, a detailed model like the boundary element method could characterize a complicated noise mitigation device versus a simple reference device. This presentation discusses the initial development of this hybrid method.

8:45

1aNS2. Predicted effects of meteorology on ground treatments. Shahram Taherzadeh (Eng. & Innovation, The Open Univ., Walton Hall, Milton Keynes MK7 6AA, United Kingdom, shahram.taherzadeh@open.ac.uk)

This presentation reports on calculations carried out to investigate the effect of meteorological conditions on the performance of ground treatments for traffic noise reduction. These treatments include placing strips of acoustically soft or rough surfaces near the source. The soft or rough strip can be raised up to 30 cm. In other words, the height of the rough elements can be as much as 30 cm. Their upper surface height can also be the same as the ground surface or, in other words, the treatments can be recessed. We present and discuss numerical predictions of the influence of downwind and upwind conditions on the insertion loss of raised and recessed, acoustically soft strips or strips of roughness elements in 2D using a Parabolic Equation code.

9:00

1aNS3. Hierarchical modeling approach to community noise annoyance. D. Keith Wilson (Cold Regions Res. and Eng. Lab., U.S. Army ERDC, 72 Lyme Rd, Hanover, NH 03755-1290, D.Keith.Wilson@usace.army.mil), Nicole M. Wayant (Geospatial Res. Lab., U.S. Army ERDC, Alexandria, VA), Edward T. Nykaza (Construction Eng. Res. Lab., U.S. Army ERDC, Champaign, IL), Chris L. Pettit (Aerosp. Eng. Dept., U.S. Naval Acad., Annapolis, MD), and Chandler M. Armstrong (Construction Eng. Res. Lab., U.S. Army ERDC, Champaign, IL)

Previous efforts to predict community noise annoyance from objective measurements of sound exposure have been confounded by the large and unexplained scatter in survey data. We hypothesize that community noise annoyance can be rationally modeled and predicted through a hierarchical (multilevel) statistical paradigm, which incorporates variations in tolerance among individuals and communities. Simulations based on this conceptual model indicate that the individual- and community-level variations have distinct statistical signatures, both of which are clearly evident in existing meta-analyses of annoyance to transportation noise. We thus perform regression analyses of transportation noise annoyance using a multilevel, generalized linear model (GLM), which is statistically consistent with the conceptual model. The multilevel model strikes a compromise between no pooling and complete pooling of survey data, and enables the noise tolerances and their variations at the multiple model levels to be distinguished and quantified.

9:15

1aNS4. Classification of environmental noise sources using machine-learning methods. Edward T. Nykaza (ERDC-CERL, 2902 Newmark Dr., Champaign, IL 61822, edward.t.nykaza@usace.army.mil), Arnold P. Boedihardjo (ERDC-GRL, Alexandria, VA), Matthew G. Blevins, Andrew M. Hulva (ERDC-CERL, Champaign, IL), and Dan Valente (Chartbear, New York, NY)

Unattended and continuously running environmental noise monitoring systems can capture an intractable amount of data. The signals captured can include a multitude of sources (e.g., wind noise and anthropogenic noise sources) in addition to the environmental noise sources of interest (e.g., aircraft, vehicles, trains, and military weapons). In this presentation, we explore the use of machine-learning methods to effectively isolate and identify environmental noise sources captured on such a noise monitoring system. Specifically, we consider the use of both unsupervised (e.g., principle components analysis, clustering methods, and deep belief networks) and supervised (e.g., logistic regression, support vector machines, and neural networks) pattern-learning methods to derive the features of interest and classify the signals based on the obtained features. The generalization performance of each method is assessed using a dataset of over 120,000 human classified signals, and the strengths and weaknesses of each approach are discussed.

9:30

1aNS5. Using blind signal processing algorithms to remove wind noise from environmental noise assessments: A wind turbine amplitude modulation case study. Paul Kendrick, Sabine von Hünerbein, and Trevor J. Cox (Acoust. Res. Ctr., The Univ. of Salford, Newton Bldg., Salford M5 4WT, United Kingdom, t.j.cox@salford.ac.uk)

Microphone wind noise can corrupt outdoor measurements and recordings. It is a particular problem for wind turbine measurements because these cannot be carried out when the wind speed is low. Wind shields can be used, but often the sound level from the turbine is low and even the most efficient shields may not provide sufficient attenuation of the microphone wind noise. This study starts by quantifying the effect that microphone wind noise has on the accuracy of two commonly used Amplitude Modulation (AM) metrics. A wind noise simulator and synthesized wind turbine sounds based on real measurements are used. The simulations show that even relatively low wind speeds of 3 m/s can cause large errors in the AM metrics. Microphone wind noise is intermittent, and consequently, one solution is to analyze only uncorrupted parts of the recordings. This paper tests whether a single-ended wind noise detection algorithm can automatically find uncorrupted sections of the recording, and so recover the true AM metrics. Tests showed that doing this can reduce the error to ±2 dBA and ±0.5 dBA for the time and modulation-frequency domain AM metrics, respectively.

9:45–10:00 Break

10:00

1aNS6. Active noise control of rocket engine noise in an engine test facility for quiet nearby communities. Kwanhyung Lee and Yong Joe Kim (Texas A&M Univ., 1537 Pine Ridge Apt C, College Station, TX 77840, rhksgud92@tamu.edu)

The objective of this research project is to develop an Active Noise Control (ANC) system based on the Filtered-X Least Mean Square algorithm. The ANC system developed here will be installed in a rocket engine testing facility of SpaceX Company near McGregor, Texas. As the SpaceX Company's rocket engines have been increased in their powers, the engine noise from the testing facility is increasing rapidly. Although there is no noise complain currently from the nearby communities in McGregor, concerns are expected in the near future that the noise could possibly disturb people in McGregor. The ANC system can reduce the noise level using a few microphones and speakers connected to a DSP frontend, while a Passive Noise Control system would be much larger and require a higher cost to be implemented. This ANC system is currently implemented as a Single Input and Single Output system in a laboratory, effectively reducing the noise generated from a loudspeaker driven by the recorded rocket engine noise signal. Then, the system will be improved and operated as a Multiple Inputs and Multiple Outputs system to successfully adapt various wind, temperature, and humidity changes, leading to the maximum noise reduction toward McGregor.

10:15

1aNS7. Measurements and player surveys of crowd noise levels during college hockey ames. Brenna N. Boyd and Lily M. Wang (Durham School of Architectural Eng. and Construction, Univ. of Nebraska-Lincoln, 1110 S. 67th St., Omaha, NE 68182-0816, bnboyd@unomaha.edu)

Measuring crowd noise in football stadiums has become popularized by the media in recent years, as teams have vied for the right to claim to have the "loudest stadium." Many fans believe that the louder they cheer, the more likely their team will win. While cheering gives players mental support, the extraneous noise could also be detrimental to effective communications on the field. Based on Barnard's previous study of crowd noise at outdoor football games (2011), the present study focuses on hockey arenas which, unlike football stadiums, typically have roofs that can add more surface area for sound to amplify. Measurements of the crowd noise levels and surveys of hockey players have been taken during four college hockey games within a closed-roof stadium. Results will be presented and discussed, with focus on determining the loudest section, if there is noise interference on the ice, and if there is correlation between noise level and goals acquired by the home team.

10:30

1aNS8. Road traffic noise mapping in the Federal University of Santa Maria, Brazil. Olmiro C. de Souza Neto (UFSM, Acampamento, 569, Santa Maria, Santa Maria 97050003, Brazil, olmirocz.eac@gmail.com) and Stephan Paul (Ctr. of Mobility Eng. and Lab. of Vib. and Acoust., UFSC, Joinville, Brazil)

The Federal University of Santa Maria is an academic community with teaching units, leisure and resting places, and a hospital. This different uses require that environmental noise limits, as given by international and national recommendations, are respected. Noise maps are one of the tools that can be used for soundscape evaluation and to check conformity with requirements. In this project, the data necessary for the development of the noise map of UFSM university campus have been collected, taking the traffic of motor vehicles on the campus as mayor noise source. A methodology for data collection was created based on the bibliography and input data required by the software. Noise maps, in terms of day sound pressure level isolines, were then generated by the software SoundPLAN 7.1. The noise map created shows that 35% of the teaching units are overexposed to road traffic noise and 45% of the students may be under negative effects of the road noise. It was also discovered that the most noise sensitive units, that are the hospital, a high school, and a day care center, have their facades exposed to day sound pressure levels higher than the recommendations.

10:45

1aNS9. Ordinal response model of community response. Chandler M. Armstrong and Edward T. Nykaza (ERDC-CERL, 2902 Newmark Dr., Champaign, IL 61822, edward.t.nykaza@usace.army.mil)

Those analyzing community response to noise data often collapse ordinal scale data into a binomial variable to predict the percentage of the community that will be highly annoyed at given a noise dose. Collapsing the data simplifies the model, but also discards potentially useful information. An ordinal response model is one way to use all the information available in ordinal scale data. This paper compares the conventional binomial model to an ordinal response model to demonstrate the benefits and drawbacks of each. We have found that the ordinal response model may be a better option because some independent variables only influence response to noise at the lower end of the ordinal scale. The ordinal response model can detect effects across the entire ordinal range whereas the binomial model examines only the highly annoyed end of the scale.

11:00

1aNS10. Choosing noise dose bin widths when modeling community response to noise. Nicole Wayant (ERDC-GRL, Alexandria, VA), Edward T. Nykaza (ERDC-CERL, 2902 Newmark Dr., Champaign, IL 61822, edward.t.nykaza@usace.army.mil), D. Keith Wilson (ERDC-CRREL, Hanover, NH), and Chandler M. Armstrong (ERDC-CERL, Champaign, IL)

While there are many studies on how communities respond to noise, there are few that explicitly define how the noise dose, used to fit community response models, are binned. When modeling the dose response relationship between noise and community annoyance, the choice of the noise bin width can drastically affect the community response or tolerance models fit to the data. To explore the optimal noise bin width, we fit various dose response models to bin widths between 1 and 10 dB and data that had been divided into bins of varying widths but an equal number of points in each bin. Additionally, we fit the models using a weighted regression procedure that weights each bin by its number of points, and find that this approach mitigates the modeling errors implicit to the (often arbitrary) noise bin width decision.

Session 1aPA

Physical Acoustics, Structural Acoustics and Vibration, and Engineering Acoustics: Phononic Metamaterials I

Joel Mobley, Chair
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Chair's Introduction—8:35

Invited Papers

8:40

1aPA1. Wave control with acoustic metasurfaces. Steven Cummer, Yangbo Xie, Wenqi Wang, and Bogdan-Ioan Popa (Duke Univ., PO Box 90291, Durham, NC 27708, cummer@duke.edu)

Acoustic metasurfaces are thin, engineered structures that can control the local reflection and transmission phase of acoustic waves, and thus enable a high degree of flexibility of wave manipulation. They are currently under active investigation by a multiple research groups for diffractive acoustic elements, surface mode excitation, extraordinary wave transmission, and a number of other possible applications. We will describe our recent work in the area of acoustic metasurfaces based on both rigid labyrinthine passive structures and piezoelectric-based active structures. Specific topics will include optimization of passive metasurface structure, nonlinear and reconfigurable active metasurfaces, and control of acoustic diffraction and surface waves with periodic metasurfaces.

9:00

1aPA2. Soft 3D acoustic metamaterials. Thomas Brunet, Olivier Poncelet, Christophe Aristégui (Université de Bordeaux, I2M, 351, cours de la libération, Bâtiment A4 - I2M/APY, Talence 33405, France, thomas.brunet@u-bordeaux.fr), Jacques Leng (Université de Bordeaux, LOF, Pessac, France), and Olivier Mondain-Monval (Université de Bordeaux, CRPP, Pessac, France)

One of the current challenges in the field of metamaterials is to extend beyond electromagnetism in other areas such as acoustics [1]. Soft matter techniques coupled with microfluidics provide a unique tool to take up this challenge because they allow for the production of 3D locally resonant (random) materials composed of various soft resonators [2]. The Mie (or cavity) resonators are interesting key elements for acoustic metamaterials since they may induce strong acoustic resonances provided large sound-speed contrasts between the inclusions and the host matrix [3]. For example, the use of "slow" (deformable) ferrofluid-droplets allows for the tuning of sharp Mie resonances, thanks to external magnetic fields [4]. For much higher sound-speed contrasts, we have recently shown that strong Mie resonances of "ultra-slow" beads made of soft porous silicone rubbers [5] could induce strong dispersion effects leading to materials with exotic (zero, negative) values of the acoustic index [6]. [1] Wegener, *Science* **342**, 939–940 (2013). [2] Brunet *et al.*, *Science* **342**, 323–324 (2013). [3] Li and Chan, *Phys. Rev. E* **70**, 055602 (2004). [4] Brunet *et al.*, *Phys. Rev. Letters* **111**, 264301 (2013). [5] Zimny *et al.*, *Langmuir* **31**, 3215–3221 (2015). [6] Brunet *et al.*, *Nature Mater.* **14**, 384–388 (2015).

9:20

1aPA3. Acoustic wave control with cylindrical metamaterial elements in water. Andrew Norris, Alexey S. Titovich (Mech. and Aerosp. Eng., Rutgers Univ., 98 Brett Rd., Piscataway, NJ 08854, norris@rutgers.edu), and Michael Haberman (The Univ. of Texas at Austin, Austin, TX)

Devices based on transformation acoustics (TA) designed to control radiation of acoustic waves in water will be described. By restricting the TA mapping to a two-dimensional conformal transformation, it is shown that the properties in the physical device have constant density equal to the background density, while the effective acoustic medium must have spatially varying compressibility with values proportional to the area mapping. The talk will concentrate on the application of these ideas to a conformal TA device, the circle-to-square lens. A practical design procedure based on unit solid cylinder metamaterial elements will be described. The selection of elements is simplified using an Ashby-type chart of properties in terms of effective cylinder density vs. compressibility. Unlike previous gradient index lens devices of this type, the present design is almost optimally impedance and index matched. Analytical, numerical, and experimental results will be presented for a device with only 49 elements showing broadband focusing with positive gain in the preferred directions. [Work supported by ONR.]

9:40

1aPA4. Source driven homogenization and spatial dispersion effects in acoustic metamaterials. Caleb F. Sieck (Appl. Res. Labs. and Dept. of Elec. and Comput. Eng., The Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758, csieck@arlut.utexas.edu), Michael B. Muhlestein (Appl. Res. Labs. and Dept. of Mech. Eng., The Univ. of Texas at Austin, Austin, TX), Andrea Alù (Dept. of Elec. and Comput. Eng., The Univ. of Texas at Austin, Austin, TX), and Michael R. Haberman (Appl. Res. Labs. and Dept. of Mech. Eng., The Univ. of Texas at Austin, Austin, TX)

Acoustic metamaterials (AMM) composed of dynamic subwavelength heterogeneities in a host fluid may generate an overall response that can be represented with dynamic effective parameters such as negative dynamic density or compressibility. Dynamic parameters imply that highly variable effective wavelengths exist even in the long wavelength limit where $k_0a << 1$, with k_0 representing the wavenumber in the host and a the descriptive size of the heterogeneity. The variability in effective wavelength is the result of strong frequency dispersion, often accompanied by nonlocal and spatial dispersion effects that complicate efforts to correctly homogenize the medium. This work presents a three-dimensional, source-driven, non-local homogenization scheme for a periodic AMM composed of a host fluid containing dynamic heterogeneities. The resulting constitutive relations couple macroscopic volume-strain and momentum fields and are analogous to the Willis relations of elastodynamics and bianisotropy in electromagnetism. The model accounts for first-order spatial dispersion effects in the long wavelength limit and reveals the origins of coupled field response. One dimensional examples of AMM will be used to demonstrate the homogenization procedure and the effects of spatial dispersion. [Work supported by ONR.]

10:00–10:30 Break

Contributed Papers

10:30

1aPA5. The acoustic magician hat: Broadband acoustic cloaking within a cavity with hard boundaries. Weiwei Kan (Dept. of Electron. Eng., Universitat Politecnica de Valencia, Nanjing, Nanjing, China), Garcia-Chocano M. Victor, Francisco Cervera (Dept. of Electron. Eng., Universitat Politecnica de Valencia, Valencia, Valencia, Spain), Bin Liang, Xin-ye Zhou, Lei-lei Yin (Dept of Phys., Univ Nanjing, Nanjing, China), Jianchun Cheng (State Key Lab. of Acoust., Chinese Acad. of Sci., Beijing, Beijing, China), and Jose Sanchez-Dehesa (Dept. of Electron. Eng., Universitat Politècnica de València, Wave Phenomena Group, Valencia, Valencia ES-46022, Spain, jsdehesa@upv.es)

This work reports the design, fabrication, and experimental validation of a broadband acoustic cloak for the concealing of three-dimensional (3D) objects placed inside an open cavity with arbitrary surfaces. This 3D cavity cloak represents the acoustic analogue of a magician hat, giving the illusion that a cavity with an object is empty. Transformation acoustics is employed to design this cavity cloak, whose parameters represent an anisotropic acoustic metamaterial. A practical realization is made of perforated layers fabricated by drilling subwavelength holes on 1-mm-thick Plexiglas plates. In both simulation and experimental results, concealing of the reference object by the device is shown for airborne sound with wavelengths between 10 cm and 17 cm.

10:45

1aPA6. Analysis of cloaks for flexural waves. Alfonso Climente (Dept. of Electron. Eng., Universitat Politecnica de Valencia, Valencia, Valencia, Spain), Daniel Torrent (Universite de Bordeaux, Bordeaux, France), and Jose Sanchez-Dehesa (Dept. of Electron. Eng., Universidad Politecnica de Valencia, Wave Phenomena Group, Valencia, Valencia ES-46022, Spain, jsdehesa@upv.es)

We report a comprehensive analysis of the cloaks proposed for bending waves propagating in a thin metallic plate. The analysis uses a semi-analytical model which is able to reproduce the experimental data reported by Stenger and coworkers [see Phys. Rev. Lett., vol. 108, 014301 (2012)]. The model is based on the Kirkoff-Love equation of motion and employs the multilayer scattering algorithm to calculate the interaction of the propagating waves with the cloak. The boundary equations apply to the designed device give a complete description of the data without using simplified algorithms solved in a finite element framework. The performance of the cloak is characterized with the visibility factor, a parameter already employed in several acoustic cloaks. A discussion will be given of the performance of the cloak for flexural waves in comparison with acoustic cloaks. [Work supported by ONR.]

11:00

1aPA7. Reciprocity, passivity, and causality in media with coupled strain-momentum constitutive relations. Michael B. Muhlestein (Appl. Res. Labs. and Dept. of Mech. Eng., The Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758-4423, mimuhle@gmail.com), Caleb F. Sieck, Andrea Alù (Appl. Res. Labs. and Dept. of Elec. and Comput. Eng., The Univ. of Texas at Austin, Austin, TX), and Michael R. Haberman (Appl. Res. Labs. and Dept. of Mech. Eng., The Univ. of Texas at Austin, Austin, TX)

Metamaterials are heterogeneous materials and structures which, under certain circumstances, may be interpreted as a homogeneous material displaying extreme physical properties such as negative effective density or modulus. Acoustic metamaterials (AMM) therefore expand the parameter space for acoustic device design and are thus of interest for a wide range of applications. Most AMM are composed of linear and passive constituent materials. Any physically meaningful approximation of their overall response must therefore obey reciprocity, passivity, and causality. This requirement constrains the effective parameters and delineates the range of possible material properties for an AMM. While restrictions for standard constitutive equations in acoustics and elastodynamics are well known, they have not been explored in detail for media with coupled strain-momentum behavior which is required to fully describe AMM [Norris *et al.*, Proc. R. Soc. A, **467**, 1749–1769 (2011)]. This work derives the restrictions on coupled acoustic constitutive equations by requiring the overall response to be reciprocal, passive, and causal. The special cases of lossless and very low-loss materials are then considered and some useful approximate restrictions are also presented. Restrictions for the analogous case of generally anisotropic elastic strain-momentum coupled media will also be reported. [Work supported by ONR.]

11:15

1aPA8. Non-reciprocity and refraction of elastic waves in a solid with aligned parallel gaps. Xiaoshi Su and Andrew Norris (Mech. and Aerosp. Eng., Rutgers Univ., 98 Brett Rd., Piscataway, NJ 08854, xiaoshi.su@rutgers.edu)

Non-reciprocal and refractive devices for elastic waves are designed using a solid with aligned parallel gaps. The gaps are assumed to be thin so that they can be considered as parallel rectangular cracks separating effective thin plates. To formulate the transmission and reflection coefficients for SV- and P-wave, an analytical model is established using thin plate theory with displacement and force continuous at the junction between plate and exterior body. The analytical model compares well with full FEM simulations. The non-reciprocity effect for P-waves is achieved by sending an incident P-wave at a critical angle, at which total conversion to SV-wave

happens, with respect to the normal of a free boundary. An array of parallel gaps perpendicular to the propagation direction of the reflected waves stop the SV-wave but let P-wave travel through. Thus, the energy transmission is high from one side to another and is low from the opposite direction. The refractive effect for SV-waves is achieved by choosing the slope of the edge of plate array, and plate members for $|T| = 1$ at the same frequency with the ratio between plate length and flexural wavelength fixed. Examples of elastic non-reciprocal and wave steering devices will be discussed.

11:30

1aPA9. Acoustic metasurfaces for asymmetric transmission. Chen Shen and Yun Jing (Mech. and Aerosp. Eng., North Carolina State Univ., 3131-I Walnut Creek Pkwy, Raleigh, NC 27606, cshen5@ncsu.edu)

We present a design of acoustic metasurfaces yielding highly asymmetric transmission within a certain frequency band. The design consists of a bottom layer of gradient-index metasurface and a top layer of low refractive index metasurface. When the incident waves transmit from the bottom side, the wave-front will be steered, and the total reflection occurs on the boundary of the top layer, leading to extremely low transmission. When the incident waves transmit from the top side, the transmission is high as the impedance of the low refractive index metasurface is matched with the background medium. Numerical simulations show that the transmission contrast between the two incident directions is high within a certain frequency band. Compared to previous designs, the proposed one can be more compact. This design may have potential applications in ultrasound imaging and noise reduction.

11:45

1aPA10. Design of one-way acoustic energy flow devices using Bayesian network classifiers. Benjamin M. Goldsberry, Stephanie G. Konarski, Timothy Klatt, and Michael R. Haberman (Appl. Res. Labs. and Dept. of Mech. Eng., Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758, bmgoldsberry@gmail.com)

Linear acoustic metamaterials (AMM) displaying dynamic negative stiffness or density have been the subject of current research to design exotic devices such as acoustic super-lenses and cloaks. More recently, nonlinear AMM have been of interest as one means of creating non-reciprocal acoustic devices [Liang *et al*., Nat. Mater. **9** (2010)]. The efficiency of those types of non-reciprocal acoustic devices strongly depends on the material nonlinearity of one of its components and is therefore limited by existing fluids containing contrast agents. This work addresses this limitation by exploring the top-down design of a nonlinear AMM with non-resonant subwavelength structures that display non-monotonic pressure-volume strain response to generate an AMM with large parameters of nonlinearity. A simple one-way device consisting of a frequency-selective acoustic mirror and a nonlinear medium is described using a nonlinear multiscale model and a nonlinear propagation model that includes quadratic and cubic nonlinearity. Bayesian network classifiers (BNC) map regions of high performance at the device scale to each design level and intersect the high performance space across levels to identify multilevel solutions. Three design levels are considered: one-way performance, nonlinear acoustic propagation in the effective medium, and effective properties of the AMM based on subwavelength structure.

MONDAY MORNING, 2 NOVEMBER 2015 CITY TERRACE 7, 8:30 A.M. TO 11:40 A.M.

Session 1aSP

Signal Processing in Acoustics, Underwater Acoustics, and Animal Bioacoustics: Direction of Arrival (DOA) Estimation, Source Localization, Classification and Tracking Using Small Aperture Arrays I

R. Lee Culver, Cochair
ARL, Penn State University, PO Box 30, State College, PA 16804

Geoffrey H. Goldman, Cochair
U.S. Army Research Laboratory, 2800 Powder Mill Road, Adelphi, MD 20783-1197

Chair's Introduction—8:30

Invited Papers

8:35

1aSP1. Some aspects of signal and array processing with small aperture underwater acoustic arrays. Gerald L. D'Spain and Camille Pagniello (Marine Physical Lab, Scripps Inst. of Oceanogr., 291 Rosecrans St., San Diego, CA 92106, gdspain@ucsd.edu)

Signal and array processing with small aperture acoustic arrays is a critical issue when physical space for sensor deployment is limited, often the case in ocean acoustics. This presentation discusses processing issues and performance of various algorithms applied to data from these arrays. In 1954, Pritchard showed that as the ratio of the inter-hydrophone spacing to acoustic wavelength approached zero, the maximum directivity index approached a non-zero value. This phenomenon of "superdirectivity," where array weights become large and opposite in sign, can be understood in terms of a Taylor series expansion of the pressure field. This expansion also illustrates that an acoustic vector sensor is equivalent to a small volumetric hydrophone array, so that data processing issues for both array types is similar, although the primary sources of self noise differ. Formally, measurement of direction of arrival (DOA) is a parameter estimation problem. Therefore,

performance is quantified by the statistical distribution (bias and variance) of the estimates. Therefore, although the spatial resolution of adaptive beamformers and the array gain may be higher than conventional approaches, the statistical estimation performance may be similar. These points will be illustrated using actual ocean acoustic data. [Work supported by the Office of Naval Research.]

8:55

1aSP2. Symmetric small-aperture arrays for three-dimensional bearing estimation. David C. Swanson (Appl. Res. Lab, Penn State Univ., PO Box 30, State College, PA 16804, dcs5@arl.psu.edu) and Richard L. Culver (Penn State Univ., Chevy Chase, MD)

Small aperture arrays (size less than a wavelength) can be used for passive direction of arrival (DOA) estimation of both broadband and narrowband signals in the frequency domain. Phase differences across the array are measured in the frequency domain and can be spectrally averaged for stationary DOA and frequencies if desired. Data windowing will bias the DOA measurement toward the center of the FFT data buffer and is useful to prevent spectral leakage from strong target signals overshadowing weak target signals. The array is capable of measuring multiple target DOAs so long as each target produces unique frequencies. Broadband signals from targets can be collected from the FFT bins and grouped by arrival angle using a bearing histogram. The Cramer-Rao lower bound (CRLB) for bearing accuracy is presented as a function of frequency, aperture, and signal-to-noise ratio (SNR). The reduction in DOA accuracy due to a small aperture can be overcome if the SNR is sufficiently high. Using symmetry in 2D and 3D array geometries, we show how the azimuth and elevation angles can be separately measured. Examples are given for several single and multiple targets and different array shapes.

9:15

1aSP3. Direction-of-arrival estimations based on a two-microphone array using two levels of Bayesian inference. Ning Xiang (Graduate Program in Architectural Acoust., Rensselaer Polytechnic Inst., Greene Bldg., 110 8th St., Troy, NY 12180, xiangn@rpi.edu) and Jose Escolano (Sophandrey Res., Brooklyn, NY)

Due to a wide variety of potential applications, such as in video conferencing, mobile devices, and robotics, sound source localization using a small aperture consisting of only two microphones has been actively investigated. Based on the observed time-differences of arrival between sound signals, a probability distribution of the direction of the sources is derived to estimate the actual direction of sources. Many existing algorithms, however, assume a given number of sound sources. This paper describes a recent development in a model-based Bayesian probabilistic approach by Escolano *et al.* [J. Acoust. Am. Soc. 135, 742–751 (2014)], which allows both the number and direction of speech sources to be inferred. This paper will demonstrate that a unified framework encompassing two levels of Bayesian inference, model selection and parameter estimation, can be efficiently applied in this challenging task. This paper will also present different experimental setups and scenarios to investigate the performance of the proposed method.

Contributed Paper

9:35

1aSP4. Multiple and single snapshot compressive beamforming. Peter Gerstoft (Scripps Inst. of Oceanogr., Univ. of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0238, gerstoft@ucsd.edu), Angeliki Xenaki (Dept. of Appl. Mathematics and Comput. Sci., Tech. Univ. of Denmark, Kgs.Lyngby, Denmark), and Christoph F. Mecklenbrauker (Christian Doppler Lab, Inst. of Telecommunications, TU Wien, Vienna, Austria)

For a sound field observed on a sensor array, compressive sensing (CS) reconstructs the direction-of-arrival (DOA) of multiple sources using a sparsity constraint. The DOA estimation is posed as an underdetermined problem by expressing the acoustic pressure at each sensor as a phase-lagged superposition of source amplitudes at all hypothetical DOAs. Regularizing with an ℓ_1-norm constraint renders the problem solvable with convex optimization, and promoting sparsity gives high-resolution DOA maps. Here, the sparse source distribution is derived using maximum a posteriori (MAP) estimates for both single and multiple snapshots. CS does not require inversion of the data covariance matrix and thus works well even for a single snapshot where it gives higher resolution than conventional beamforming. For multiple snapshots, CS outperforms conventional high-resolution methods, even with coherent arrivals and at low signal-to-noise ratio. The superior resolution of CS is demonstrated with vertical array data from the SWellEx96 experiment for coherent multi-paths.

Invited Papers

9:50

1aSP5. Small aperture microphone arrays. Gary W. Elko (mh Acoust., 25A Summit Ave., Summit, NJ 07901, gwe@mhacoustics.com) and Jens Meyer (mh Acoust., Burlington, VT)

Superdirectional microphone arrays are arrays that are typically smaller than the acoustic wavelength and attain directional gains that exceed those of a classical delay-sum beamformer. Early superdirectional microphones utilized a combination of a velocity microphone along with a pressure microphone. Later, a single sensor superdirectional microphone was discovered that utilized the combination of pressure and pressure-difference (which is proportional to the acoustic particle velocity) through appropriate porting of the incident acoustic field to both sides of the microphone diaphragm. In the early 1980s, with the advent of multichannel FFT analyzers, there was a renewed interest in using superdirectional microphone arrays to estimate the acoustic intensity and to calculate the acoustic power flow from sources. The estimation of the vector acoustic intensity led to many transducer designs that utilized up to 6 pressure microphones and commensurate signal processing. In this talk we will show some of the early acoustic intensity probes that were designed to estimate the acoustic intensity. These small arrays have been utilized in many other beamforming applications. We will show one where a superdirectional beamformer is also capable of source direction finding by utilizing some simple adaptive beamformer implementations.

10:10–10:25 Break

10:25

1aSP6. On robust time delay estimation in room acoustic environments. Jingdong Chen (Ctr. of Intelligent Acoust. and Immersive Communications, Northwestern Polytechnical Univ., 127 Youyi West Rd., Xi'an, Shaanxi 710072, China, jingdongchen@ieee.org), Jacob Benesty (INRS-EMT, Univ. of PQ, Montreal, QC, Canada), and Gongping Huang (Ctr. of Intelligent Acoust. and Immersive Communications, Northwestern Polytechnical Univ., Xi'an, Shaanxi, China)

Time delay estimation, which serves as the first stage that feeds into subsequent processors for localizing and tracking radiating sources, has been an active research topic for decades. This paper deals with time delay estimation in room acoustic environments. The major focus is on developing algorithms that can achieve robust time delay estimates in reverberant and noisy environments. Three approaches are investigated, i.e., the blind channel identification based method, the multichannel cross correlation based technique, and a method based on the use of the Householder transformation. The first approach achieves its robustness with respect to reverberation by taking into account reverberation in the problem formulation; the second one improves the robustness by exploiting the redundancy provided by multiple microphones, and the third method attempts to separate noise and reverberation from the signal components. Experimental results are presented to illustrate their performance and pros and cons in room acoustic environments where reverberation and noise are commonly encountered.

10:45

1aSP7. Small infrasonic arrays for direction of arrival estimation. W. C. Kirkpatrick Alberts and Stephen M. Tenney (US Army Research Lab., 2800 Powder Mill, Adelphi, MD 20783, kirkalberts@verizon.net)

Long infrasonic wavelengths suggest a requirement for large arrays. This coupled with constraints in space can lead to array sizes and shapes that must strike a balance between the available resources and the tasks of the array; rarely are these arrays able to be installed in an optimal configuration. Further, typical frequencies of military interest span an order of magnitude in wavelength, roughly 17 to 170 m. However, standard beamforming techniques yield acceptable results even in frequency ranges where the spatial limitations of the available real estate force the size of the array to be much smaller than the wavelengths of a given signal of interest. Results acquired by processing several spatially constrained infrasonic arrays using standard techniques, e.g., minimum variance distortionless response (MVDR), will be discussed.

11:05

1aSP8. Comparison of direction on arrival estimates from a co-located vector sensor and horizontal line array. David R. Dall'Osto (Acoust., Appl. Phys. Lab. at Univ. of Washington, 1013 N 40th St., Seattle, WA 98105, dallosto@apl.washington.edu) and Peter H. Dahl (Mech. Eng., Univ. of Washington and Appl. Phys. Lab., Seattle, WA)

Direction of arrival (DOA) estimates made simultaneously by a vector sensor and a co-located 1.4 m long horizontal line array (HLA) are compared. The 8-channels of data, corresponding to four HLA pressure sensors and a vector sensor (3-orthogonal particle acceleration sensors + 1 pressure sensor), were coherently recorded by an autonomous bottom-deployed system. The system was deployed 4 km off the coast of Panama City, FL, in water 20 m deep. Recordings were made of a series of 1–4 kHz transmissions (100-ms duration) produced by source suspended 12 m below a drifting vessel. GPS measurements of the source location for each transmission show a source heading changing by 90 degrees relative to the sensor system as the source passes to within 200 m before opening to range 1200 m. The performance of DOA estimates from vector sensor measurements of active intensity and from HLA beamforming, using both conventional methods and compressive sensing, are assessed relative to the measured source bearing. At certain source locations DOA estimates deviate significantly from the source bearing. This effect is shown to be caused by destructively interfering modes, which can produce DOA estimates in the opposite direction of the source bearing.

Contributed Paper

11:25

1aSP9. Analysis and design of multi-pole vector sensor arrays. Junyuan Guo, Shie Yang, and Shengchun Piao (College of Underwater Acoust. Eng., Harbin Eng. Univ., NO.145, Nantong St., Nangang District, Harbin, Heilongjiang Province, Harbin 150001, China, guojunyuan@hrbeu.edu.cn)

Super-directive sensor arrays, due to their small size and enhanced directivity, are quite promising in signal-to-noise enhancement and target direction finding. An array design method, which can build a desired beam pattern using compact multi-pole sensor arrays, is presented in this paper. The proposed method extracts multi-pole modes of different order from the spatial differentials of the sound fields which are measured by a uniform square array composed with hydrophones and particle velocity sensors. It can achieve more benefits with the employment of particle velocity sensors because of their inherent dipole directivities. The spatial differential in the extraction procedure is approximated with spatial difference and the approximation decreases the beam pattern performance. The performance degradations in multi-pole beam patterns are investigated for different incident wave frequency. Simulation and analysis show that the array gain is to a certain extent robust to uncorrelated noise.

Session 1pAA

Architectural Acoustics: Sustainability and Acoustics

Lucky S. Tsaih, Cochair
Dept. of Architecture, National Taiwan Univ. of Sci. and Tech., 43 Keelung Rd., Sec. 4, Taipei 10607, Taiwan

Ronald Eligator, Cochair
Acoustic Distinctions, 145 Huguenot Street, New Rochelle, NY 10801

Chair's Introduction—2:00

Invited Papers

2:05

1pAA1. Synergies between high performance buildings and good acoustics. Ralph T. Muehleisen (Energy Systems, Argonne National Lab., 9700 S. Cass Ave., Bldg. 221, Lemont, IL 60439, rmuehleisen@anl.gov)

Post-occupancy surveys and anecdotal evidence suggest that "green" buildings tend to have worse acoustics than new "non-green" and older buildings. While some aspects of green building design such as the increased use of glass, increased exposure of hard finishes, and the removal of barriers between work stations can create situations that reduce the acoustic performance of interior spaces, all is not lost. Many energy efficiency innovations can actually improve acoustic performance. In this presentation, some of the synergies between acoustics and high performance building design will be discussed.

2:25

1pAA2. A look at designing and integrating acoustics and sustainability. Shane J. Kanter, Robin Glosemeyer Petrone, Carl Giegold, Greg Miller, Scott Pfeiffer, and Brad Fritz (Threshold Acoust., 53 W. Jackson Blvd., Ste. 815, Chicago, IL 60604, skanter@thresholdacoustics.com)

Designing with sensitivity toward our natural environment relates not only to the resources that are used in the design, construction, and ongoing operation of buildings, but also to creating environments inspired by nature to achieve a level of comfort in our surroundings. Green building design is by no means at odds with the goals of acoustic design. An overarching byproduct of good design should be an environment that is both pleasing to the ear and to the earth's resources. These principles can be subtle and subdued, such as in the reuse of building materials in the Writer's Theatre and the design of buildings to be flexible insuring longevity for Duke University. Or, rather than pouring energy into creating materials, buildings for music can be engineered with stiffness in mind to maintain energy and body, such as in the new orchestra shell at the Lyric Opera in Chicago. More traditionally, the Tower at PNC Plaza's tagline is the "world's greenest skyscraper;" yet, the interior of the office space shows minimal obvious signs of LEED influence. Alternatively, nature's touch is right on the sleeve of the National Research Defense Counsel project with the inclusion of foliage grown directly on the walls.

2:45

1pAA3. Understanding and communicating the importance of sustainable acoustics. David S. Woolworth and Amanda G. Higbie (Roland, Woolworth & Assoc., 356 CR 102, Oxford, MS 38655, dave@oxfordacoustics.com)

A green or sustainable approach to acoustics design extends far beyond the use of green materials or meeting LEED requirements. This paper addresses the importance of understanding and using the language of sustainability, the gray area of acoustics and general exclusion from the (Mechanical-Electrical-Plumbing based) engineering conversation, and the benefits of integrated design and early inclusion of acoustics in the design process. Included will be tools and studies to communicate the advantage of sustainable acoustics practices to architects and owners.

3:05

1pAA4. Creating sustainable rooms through remediation. Joseph A. Keefe (Ostergaard Acoust. Assoc., 200 Executive Dr., STE 350, West Orange, NJ 07052, jkeefe@acousticalconsultant.com)

The author's consulting experience is that typical current sustainable design practices do not greatly affect acoustical design choices. However, many spaces are not "sustainable" due to poor acoustical performance (e.g., excessive reverberation). A few case studies of room investigations are presented, some with remediation efforts and some without, in order to evaluate how rooms can be made sustainable in the most important way: functional for their users.

3:25

1pAA5. The harmonization of sustainability and acoustics. Keely Siebein and Marylin Roa (Siebein Assoc., Inc., 625 NW 60th St., Ste. C, Gainesville, FL 32607, ksiebein@siebeinacoustic.com)

A theoretical look will be presented at how building and environmental acoustics fall into the larger context of sustainability. The 2005 World Summit on Social Development identifies sustainable development concepts as being: Social, Environment, and Economic. Each concept is examined in terms of how it relates to acoustics. For example, Social relates to communication and human interaction. Whether it is optimizing speech communication in schools, or global networking with colleagues via Internet teleconferencing, or listening to music performances in high-fidelity acoustic environments; the idea of communication is at the root of the social fabric of our society. Environment relates to materials' complete lifecycle from raw material to disposal, using recyclable materials or renewable materials that are locally harvested, reducing unwanted sonic impacts into the surroundings, and creating pleasing sounds in the environment. Economic relates to 1st cost, lifecycle cost, embodied energy, and productivity of space and users in the space. Research has shown that acoustics impacts productivity in offices, healthcare occupancies, and schools. Finding ways to navigate between competing goals in terms of other building attributes is also discussed.

3:45

1pAA6. Integrating acoustics for sustainability. Ronald Eligator (Acoust. Distinctions, 145 Huguenot St., New Rochelle, NY 10801, religator@ad-ny.com)

Sustainability is frequently correlated with energy efficiency and environmentally sensitive design. Issues such as energy use, daylight harvesting, waste management, materials manufacturing, and recyclability are all considered. More difficult to quantify but of great importance in determining whether a project is truly sustainable is the degree to which a building or space appropriately serves the function for which it was designed. Thoughtful integration of acoustic design into building projects is required to ensure the finished product will meet the design goals of the client and users, including acoustic performance requirements. Without early integrated design efforts, the need for immediate renovation or other changes to a newly completed project due to acoustic deficiencies becomes much more likely. This presentation will provide case histories of projects made successful, and therefore sustainable, through an integrated design approach. Issues related to these successful outcomes will be discussed, including budget pressures, education of the client and design team regarding the effect design decisions have on the functionality and usability of spaces, and the importance of relationship building in encouraging design team members to take on design ideas which might challenge past approaches or assumptions.

Contributed Paper

4:05

1pAA7. The Lane Community College Alveolus: A case study of sound isolation in an educational building with naturally ventilated cooling. Kent McKelvie (Cavanaugh Tocci Assoc., 327F Boston Post Rd., Sudbury, MA 01776, kmckelvie@cavtocci.com)

Providing adequate sound isolation in a building that incorporates naturally ventilated cooling presents many challenges and requires attention to detailing, along with close coordination between the acoustical consultant, architect, and project mechanical engineer. This presentation will walk through the design decisions and considerations for sound isolation at the Health and Wellness Facility for the Lane Community College in Eugene Oregon. The Lane Community College—Health and Wellness Facility is a LEED Gold certified education building that uses natural ventilation for building cooling. The building incorporates a 38-foot high by 180-foot long "lung", dubbed the Alveolus. This lung bisects the building along its full length and acts as a central chimney for evacuating warm air. Additionally, the "lung" space is constructed of translucent material so the large space can act as a light well. Using a clear (or semi-clear) polymer paneling system, the ventilation, natural lighting, and sound isolation needs were successfully balanced to meet the needs and desires of the Lane Community College.

Session 1pAB

Animal Bioacoustics and Psychological and Physiological Acoustics: Comparative Neurophysiology of the Auditory System II: Session in Honor of Albert Feng

Andrea Simmons, Cochair
Brown University, Box 1821, Providence, RI 02912

Peter M. Narins, Cochair
Integrative Biology & Physiology, UCLA, 621 Charles E. Young Dr. S., Los Angeles, CA 90095

Invited Papers

1:30

1pAB1. Albert Feng and target ranging by echolocating bats. James A. Simmons (Neurosci., Brown Univ., 185 Meeting St., Box GL-N, Providence, RI 02912, james_simmons@brown.edu)

Ultrasonic biosonar sounds propagate out to a target and return as echoes. Simultaneously, phasic-on neural responses evoked by each outbound sound propagate from one subpopulation of neurons to another at different latencies in the inferior colliculus, creating delay-lines carrying a replica of the broadcast. When each echo returns, it evokes new on-responses that travel over similar subpopulations of neurons, but lagging behind responses to the broadcast according to the delay of the echo. Albert Feng's discovery of delay-tuned neurons in the bat's nucleus intercollicularis revealed that bats "read out" echo delay from the delay-lines by detecting the succession of coincidences between responses to the echo and to the emission. Subsequent work in multiple labs demonstrated the ubiquity of delay-tuning in bats. Working in the inferior colliculus, Al Feng showed how the delay-line responses are restricted to single spikes by initial inhibition that determines each neuron's characteristic on-response latency followed by new inhibition that suppresses any subsequent multiple spikes. The interplay between timed and triggered inhibition defines the delay-lines, while delay-tuned coincidence-detecting neurons from inferior colliculus to superior colliculus guide the bat and from inferior colliculus to auditory cortex create the bat's perceived images. [Work supported by ONR.]

1:50

1pAB2. Strategies for an echolocating FM bat, *Pipistrellus abramus*, to listen to weak echoes. Hiroshi Riquimaroux (Shandong Univ.-Virginia Tech Joint Program, Shandong Univ., 27 Shanda Nanlu, Jinan, Shandong 250100, China, hiroshi_riquimaroux@brown.edu)

In Japanese house bat, *Pipistrellus abramus*, a typical FM-bat, neurophysiological investigation in the inferior colliculus showed that about half of neurons was tuned to the terminal frequency of the downward FM seep or pseudo-CF frequency for searching insects, which was around 40 kHz. Their audiograms determined by the auditory brainstem response (ABR) and the compound action potentials (CAP) of the cochlear nerve also show the lowest threshold or maximum amplitude to be found at around 40 kHz. However, we could not find a sharp notch in their audiogram around 40 kHz, which we have usually found in CF-FM bats at round their reference CF frequency. We examined the peripheral system of Japanese house bat how they extract signals of a flying insect. A particular attention was paid on their terminal frequency of FM sweep or pseudo-CF frequency. [Research supported by MEXT of Japan.]

2:10

1pAB3. Three-dimensional space representation by echolocation in bats. Melville J. Wohlgemuth, Ninad B. Kothari (Psychol. and Brain Sciences, Johns Hopkins Univ., Baltimore, MD), and Cynthia F. Moss (Psychol. and Brain Sciences, Johns Hopkins Univ., Biology-Psych. Bldg. 2123M, College Park, MD 20742, cynthia.moss@gmail.com)

Echolocating bats are equipped with a biological sonar system that permits spatial navigation and target tracking in complete darkness. By actively controlling the directional aim, timing, frequency content, and duration of echolocation signals to "illuminate" the environment, the bat directly influences the acoustic input available to its sonar imaging system. Detailed analyses of the bat's sonar behavior suggest that the animal's actions play into a rich 3-D representation of the environment, which then guides motor commands for subsequent call production, head aim, and flight control in an adaptive feedback system. Studies of the bat's sonar behavior have motivated neurophysiological studies of the midbrain superior colliculus (SC), a structure implicated in sensorimotor integration and spatial orientation. Using multichannel silicon probe recordings from the freely echolocating big brown bat, we characterized response profiles of single neurons, as the animal tracked moving targets from a stationary position on a platform and in free flight. Our data show premotor activity prior to sonar vocalizations and responses to echoes from objects. Echo responses depended on both the azimuth and delay of sonar returns. These findings demonstrate both auditory and premotor specializations in the bat SC, which contribute to the animal's 3-D representation of space.

2:30

1pAB4. Neural processing of novel sounds in the rat's inferior colliculus. Huiming Zhang, Chirag Patel, and Ariana Lumani (Dept. of Biological Sci., Univ. of Windsor, 401 Sunset Ave., Windsor, ON N9B3P4, Canada, hzhang@uwindsor.ca)

A novel sound is an occasionally occurring acoustic event in a constant/repetitive acoustic environment. Auditory neurons display sensitivity to a novel sound by reducing action potential discharges over repetitive acoustic stimulation and restoring discharges upon presence of a novel sound. We used the rat as an animal model and conducted *in vivo* neurophysiological recordings to examine how novel sounds are processed in the midbrain auditory structure, the inferior colliculus (IC). The IC receives convergent inputs from structures including those with neurons sensitive to novel sounds. These inputs have diverse sensitivities to temporal, spectral, and directional acoustic cues and produce excitatory/inhibitory synaptic events with different time courses in IC neurons. Integration among these inputs in IC neurons provides a likely physiological basis for processing the novelty of a sound and other dynamic acoustic characteristics. We used both closed- and free-field stimuli to examine responses to oddball paradigms. Our results indicate that neurons sensitive to novel sounds existed in the IC. These neurons typically have onset firing patterns; and their sensitivity to a novel sound is affected by the spatial relationship between the novel sound and a repetitive standard sound in the environment. [Research supported by NSERC of Canada.]

2:50–3:05 Break

3:05

1pAB5. Sound localization in the frog after Albert Feng: Filling in the blanks. Peter M. Narins (Integrative Biology & Physiol., UCLA, 621 Charles E. Young Dr. S., Los Angeles, CA 90095, pnarins@ucla.edu)

In his Ph.D. thesis, Albert described his elegant behavioral study demonstrating that two ears are necessary for frogs to localize sound. Next, he elucidated a series of mechanisms in the frog CNS that is responsible for encoding sound source direction. Inspired by this work, we examined some of the peripheral mechanisms involved in sound processing in the frog. For example, frogs and toads are capable of producing calls at potentially damaging levels that exceed 110 dB SPL at 50 cm. In most frog species, the tympanic membranes (TMs) communicate directly via the large, permanently open Eustachian tubes, resulting in an inherently directional asymmetrical pressure-gradient receiver. One active mechanism for auditory sensitivity reduction involves the pressure increase during vocalization that distends the TM, reducing its airborne sound sensitivity. Another states that if sounds generated by the vocal folds arrive at both surfaces of the TM with nearly equal amplitudes and phases, the net motion of the eardrum would be greatly attenuated. Both mechanisms can explain the results of our direct TM measurements. Moreover, we have measured this eardrum motion under acoustic clamp conditions and shown that blocking the internal interaural connection results in nearly azimuth-independent eardrum velocity, consistent with Albert's results.

3:25

1pAB6. Sound-triggered suppression of neuronal firing in the auditory cortex: Implications to the residual inhibition of tinnitus. Alexander Galazyuk (Anatomy and Neurobiology, Northeast Ohio Medical Univ., 4209 St. Rt. 44, Rootstown, OH 44272, agalaz@neomed.edu)

Tinnitus can be suppressed briefly following the offset of an external sound. This phenomenon, termed "residual inhibition," has been known for almost four decades, although its underlying cellular mechanism remains unknown. In our previous work, we have shown that the majority of neurons in the inferior colliculus (IC) exhibit long lasting suppression of spontaneous activity following the offset of an external sound. The time course of suppression corresponded to the time course of residual inhibition in tinnitus patients. If the suppression is an underlying mechanism, the auditory cortex (AC) neurons should also exhibit suppression because residual inhibition of tinnitus is a perceptual phenomenon. To test this hypothesis, we studied sound evoked suppression in AC neurons of awake CBA/CaJ mice using extracellular recording. Pure tones at neurons' characteristic frequency and/or wideband noise stimuli 30 s duration were delivered in the free-field. We found that AC neurons exhibited sound-triggered suppression of their spontaneous firing. Similar to the IC, the duration of this suppression was roughly corresponded to the stimulus duration (about 30 s). AC neurons also showed longer suppression to tones at their characteristic frequency than to wideband noise. Our data suggest that suppression may be a neural correlate of the residual inhibition of tinnitus in humans. [Work supported by Grant R01 DC011330 from the National Institute on Deafness and Other Communication Disorders.]

3:45

1pAB7. fMRI and electrophysiology of cortical layer-dependent processes in primary sensory cortex. Jozien Goense (Inst. for Neurosci. & Psych., Univ. of Glasgow, 58 Hillhead St., Glasgow G12 8QQ, United Kingdom, jozien.goense@glasgow.ac.uk)

To understand cortical function, it is important to better understand the cortical functional units, i.e., its columns and layers. High-resolution fMRI can offer tremendous advantages for the study of cortical circuits *in vivo*, evidenced by the increasing interest in high-resolution fMRI. However, many questions remain about the size of the cortical features that can be resolved, and how neural activity gives rise to the blood oxygenation dependent (BOLD) signal measured with fMRI. We use high-resolution fMRI combined with electrophysiology to study laminar processing, with the aim of gaining insight into the layer-dependent neural processing and the mechanisms of neurovascular coupling in the primary visual cortex (V1) and temporal lobe of awake and anesthetized macaques. We investigated whether laminar differences in the BOLD, cerebral blood flow (CBF), and volume (CBV) responses can be detected for excitatory and inhibitory stimuli, and found that the mechanisms for positive and negative BOLD responses differ, but also that neurovascular coupling differs in the cortical layers. Furthermore, neuromodulators such as dopamine can alter neurovascular coupling. Our results suggest that neurovascular coupling depends on multiple factors, and that the combination of high-resolution fMRI with electrophysiology can be used to resolve neurovascular coupling in functional microcircuits.

Session 1pAO

Acoustical Oceanography, Signal Processing in Acoustics, Underwater Acoustics, and Animal Bioacoustics: Acoustics of High Latitude Oceans II

Aaron Thode, Cochair
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John A. Colosi, Cochair
Department of Oceanography, Naval Postgraduate School, 833 Dyer Road, Monterey, CA 93943

Contributed Papers

1:15

1pAO1. Development of acoustic remote sensing techniques for sea ice, oil under sea ice, and oil encapsulated in sea ice. Christopher Bassett, Andone C. Lavery, Ted Maksym (Dept. of Appl. Ocean Phys. and Eng., Woods Hole Oceanographic Inst., Woods Hole, MA 02543, cbassett@whoi.edu), Jeremy Wilkinson (Br. Antarctic Survey, Cambridge, United Kingdom), Dajun Tang (Appl. Phys. Lab., Univ. of Washington, Seattle, WA), and Scott Pegau (Oil Spill Recovery Inst., Anchorage, AK)

Recent decreases in sea ice cover have provided new opportunities for the shipping industry and stimulated further interest in hydrocarbon extraction in Arctic waters, thereby also increasing the risk of an oil spill in ice covered waters. To support oil spill response there is a need to develop practical remote sensing techniques to detect, quantify, and map oil that is under or encapsulated in sea ice. To address this need, a series of experiments were conducted at the Cold Regions Research and Environmental Laboratory (CRREL, Hannover, NH). During these experiments, different amounts of crude oil were injected underneath artificially grown sea ice of different thicknesses. The ice and oil were monitored by a suite of instruments located in the water column, including cameras, laser fluorometers, and multibeam, narrowband, and broadband acoustic backscattering systems. In addition, temperature and salinity profiles were conducted routinely, and ice cores were collected and imaged using a micro-CT scanner. Results from the broadband acoustic backscattering system are presented, and the relative merits of this approach for the remote detection and quantification of oil under and in sea ice are discussed. In addition, the utility of the acoustic systems for studies of ice physics are also discussed.

1:30

1pAO2. A seven-year review of ambient acoustic environments in the Beaufort Sea. Kerri D. Seger, Aaron M. Thode (Scripps Inst. of Oceanogr., 9331 Discovery Way, Apt C, La Jolla, CA 92037, kseger@ucsd.edu), Susanna B. Blackwell, and Katherine H. Kim (Greeneridge Sci., Inc., Santa Barbara, CA)

Over seven seasons (2007 to 2014) Greeneridge Sciences, Inc., deployed passive acoustic recorders (DASARs) between August and October at five sites in the Beaufort Sea off the Alaskan North Slope to collect acoustic data during the fall bowhead whale migration. Each site consisted of 7–11 DASARs, arranged in triangular grids with 7 km spacing between each unit. The shallowest DASAR unit in each set was deployed 15–33 km due north of the coast in 22–39 m of water. The acoustic environments between sites differ due to varying ocean depths and sound source contributions (whales, winds, and human activities). Here, we conduct a multi-year bulk analysis of the summer Beaufort Sea acoustic environment, comparing noise properties as a function of both distance offshore and longitude within a given year, and across sites across all eight seasons. Comparisons were conducted by investigating the percentile distributions of ambient noise intensity over several bandwidths that are representative of the different sound sources present in the Beaufort Sea. Results suggest that variations in the ambient noise field across sites and years create spatially heterogeneous acoustic environments that must be accounted for when addressing responses of bowhead whales to industrial noise.

1:45

1pAO3. Modal analysis of broadband signal arrival on Beaufort shelf. Mohsen Badiey, Lin Wan, Andreas Muenchow (College of Earth, Ocean, and Environment, Univ. of Delaware, 261 S. College Ave., Robinson Hall, Newark, DE 19716, badiey@udel.edu), and David Knobles (Appl. Res. Lab., Univ. of Texas, Austin, TX)

Using previously reported temperature and salinity data collected over the past decade, time evolving sound speed profiles were constructed and used (Prog. Oceanography, 127, pp.1-20, 2014) as input to a parabolic equation model. Modeling of broadband acoustic signal propagation in the Arctic shelf-basin region during ice free sea surface season was reported recently (J. Acoust. Soc. Am. **136**(4), Pt. 2, 2317, 2014). It was shown that when broadband acoustic signals propagate from deep water to shallow water, the modal dispersion is changed. The change is mostly affected by the water thermocline behavior in time and space and by source depth. The modal arrival structure can be influenced by a number of factors including the degree of Pacific warm water intrusion, upwelling of the warm saline Atlantic water into the cold surface layer, the range-dependence of the water layers over the shelf break, and the depth of the source. In this paper, we analyze the range-dependent propagation in terms of adiabatic and coupled mode regimes in order to explain the model results. [Work supported by ONR.]

2:00

1pAO4. Investigating the effects of ocean layering and sea ice cover on acoustic propagation in the Beaufort Sea. Jason D. Sagers, Megan S. Ballard, David P. Knobles (Appl. Res. Labs. at the Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758, sagers@arlut.utexas.edu), Mohsen Badiey (College of Earth, Ocean, and Environment, Univ. of Delaware, Lewes, TX), and Andreas Muenchow (College of Earth, Ocean, and Environment, Univ. of Delaware, Lewes, DE)

Over the past several decades, the Beaufort Gyre has experienced changes in sea-ice freshwater accumulation and ocean stratification which has implications for long-range acoustic propagation. In this talk, acoustic propagation from the Canadian Basin to the Alaskan Beaufort Shelf is modeled using measurements of physical oceanography and sea ice. Water masses that impact acoustic propagation and stratification in the basin include the warm, saline Atlantic Water (AW), which is overlain by cooler, less-saline Pacific Winter Water (PWW). Oceanographic observations reveal intrusions of a warmer, fresher water mass called Pacific Summer Water (PSW). This water mass resides below the surface mixed layer, but

above the PWW and reduces acoustic interaction with the sea-ice canopy for source depths located in the halocline duct. Oceanographic data indicate that on the continental shelf, the PSW intrusion can be absent in the ice-covered months resulting in an upward refracting sound speed profile. Using measurements from ice-tethered profilers in the basin and oceanographic moorings on the shelf, we model the temporal and spatial variability of the acoustic field. The effect of scattering from the ice cover is included, with consideration given to the seasonal variability of sea-ice concentration, thickness, and acoustic properties. [Work supported by ONR.]

2:15

1pAO5. Laboratory measurements of high-frequency broadband acoustic backscatter from sea ice, oil under sea ice, and oil encapsulated in sea ice. Christopher Bassett and Andone C. Lavery (Dept. of Appl. Ocean Phys. and Eng., Woods Hole Oceanographic Inst., Woods Hole, MA 02543, cbassett@whoi.edu)

To investigate the potential for detection of crude oil under sea ice using active acoustics techniques, measurements of high-frequency broadband backscattering (75–590 kHz) from crude oil of different thicknesses (0.7–8 cm) under, and frozen within, laboratory sea ice have been performed at the Cold Regions Research and Environmental Laboratory (Hannover, NH). Backscattering measurements were performed at normal and 20 degrees from normal incidence. The data have been analyzed in both the temporal domain and in the frequency domain, allowing scattered spectra from the oil and ice to be measured. The results show structure consistent with scattering from multiple interfaces following the injection of oil under the ice and during the subsequent encapsulation the oil layer. The acoustic estimates of oil thickness are in general agreement with ancillary measurements. The sound speed of the crude oil was separately measured over a range of relevant temperatures, both to inform a scattering model and to accurately infer the oil thickness. Predictions based on a simple scattering model for the frequency-dependent reflection coefficient of oil under ice agree well with the normal incidence measurements prior to oil encapsulation. At angles off normal incidence, volume inhomogeneities appear to dominate the scattering.

2:30

1pAO6. Passive acoustic monitoring and ambient noise in the high Arctic: Resolute Bay, Nunavut. Caitlin O'Neill (School of Earth and Ocean Sci., Univ. of Victoria, 304-1000 McKenzie Ave., Victoria, BC V8X 4C8, Canada, caitlin.v.oneill@gmail.com) and Svein Vagle (Fisheries and Oceans Canada, Victoria, BC, Canada)

Resolute Bay, a remote bay in the Canadian High Arctic to the north of Parry Channel, hosts diverse populations of marine mammals that migrate through the bay each year following food availability and/or oceanographic conditions. The changing climate combined with increasing anthropogenic activity in the Arctic make it important to create an ecosystem baseline from which to predict, understand, and monitor future changes. Passive underwater acoustic observations provide a non-invasive way to monitor marine mammal presence. Broadband noise (10 Hz to 48 kHz) was recorded by an Autonomous Marine Acoustic Recorder (AMAR) and marine mammal click detections were logged by two CPODs over a 5 month period from August to December 2013. Acoustic data were processed with click and tonal call detectors to determine marine mammal presence. Resolute Bay is ice-covered 10 months a year, leading to increased broadband ambient noise levels due to ice movement. During the short open-water period, vessel activity is common in the bay. The aim is to compare these two different ambient noise regimes and how they affect the effectiveness of passive acoustic marine mammal detections and tracking.

2:45

1pAO7. Observations of thermohaline sound speed structure in the Beaufort Sea in the summer of 2015. Dominic DiMaggio, Annalise Pearson, and John A. Colosi (Dept. of Oceanogr., Naval Postgrad. School, Monterey, CA 93943, dfdimagg@nps.edu)

Moored observations of temperature and salinity were made in the depth of range 50–510 m between July 15 and August 15 2015 in the central Beaufort Sea, as part of the Canada Basin Acoustic Propagation Experiment (CANAPE) pilot study. This talk will present an analysis of the observed sound speed structure in terms of the fresh upper layer, the Pacific layers, and the Atlantic layer. The talk will also address the space/time scales of fluctuations associated with internal waves, eddies, and diffusive layering (stair cases).

3:00–3:15 Break

3:15

1pAO8. Bowhead whale localization using asynchronous hydrophones in the Chukchi Sea. Graham A. Warner, Stan E. Dosso (School of Earth and Ocean Sci., Univ. of Victoria, 3800 Finnerty Rd. Ste. A405, Victoria, BC V8P 5C2, Canada, gwarner@uvic.ca), David E. Hannay (JASCO Appl. Sci., Victoria, BC, Canada), and Jan Dettmer (School of Earth and Ocean Sci., Univ. of Victoria, Victoria, BC, Canada)

This paper estimates bowhead whale locations and uncertainties from Bayesian inversion of modally dispersed calls recorded on asynchronous recorders in the Chukchi Sea, Alaska. Bowhead calls were recorded on a cluster of seven asynchronous ocean-bottom hydrophones that were separated by 0.5–7.5 km. A warping time-frequency analysis is used to extract relative mode arrival times as a function of frequency for nine frequency-modulated whale calls that dispersed in the shallow water environment. Each call was recorded on multiple hydrophones and the mode arrival times are inverted for: the whale location in the horizontal plane, source instantaneous frequency (IF), water sound-speed profile, subbottom layering and geoacoustic parameters, relative recorder clock drifts, and residual error standard deviation, all with estimated uncertainties. A simulation study shows that accurate prior environmental knowledge is not required for accurate localization. Joint inversion of multiple recorded calls is shown to substantially reduce localization, source IF, and relative clock drift uncertainties. Whale location uncertainties are estimated between 30 and 160 m and clock drift uncertainty is estimated between 3 and 26 ms. The clock synchronization provided by the inversion is sufficient for localizing other types of marine mammal calls using simpler time-difference-of-arrival methods.

3:30

1pAO9. Resolution, identification, and stability of broadband acoustic arrivals in Fram Strait. Matthew A. Dzieciuch, Peter F. Worcester (Scripps Inst. of Oceanogr., Univ. of California, San Diego, 9500 Gilman Dr., 0225, La Jolla, CA 92093-0225, mdzieciuch@ucsd.edu), Hanne Sagen, Stein Sandven, Florian Geyer, Mohamed Babiker (Nansen Environ. and Remote Sensing Ctr., Bergen, Norway), Agnieszka Beszczynska-Möller (Inst. of Oceanology of the Polish Acad. of Sci., Sopot, Poland), and Brian D. Dushaw (Appl. Phys. Lab., Univ. of Washington, Seattle, WA)

Fram Strait is the only deep-water connection between the Arctic and the world oceans. An acoustic system for tomography, glider navigation, and passive listening was installed in the central, deep-water part of the Strait during 2010–2012, with the primary objective of improving the estimates of transport through the Strait. Previous tomographic measurements have relied on the travel times of resolved, identified, and stable acoustic arrivals. The oceanographic conditions and highly variable sea ice in Fram Strait provide an acoustic environment that differs substantially from those in other tomographic experiments, however, and results in complex arrival patterns. Comparisons of the measured arrival patterns with predictions based on hydrographic sections show that it is difficult to resolve and identify individual arrivals in the early part of the arrival patterns. In addition, the early arrivals are unstable, with the arrival structure changing significantly over time. Later arrivals that are surface-reflected, bottom-reflected tend to be easier to resolve and identify, as well as more stable. The implication is that inverse methods need to use fluctuations in the overall structure of the early arrivals, which tend to sample the ocean similarly, in combination with the travel times of the later arrivals.

3:45

1pAO10. Modeling high-frequency acoustic backscatter for remote sensing of oil under sea ice and oil encapsulated in sea ice. Dajun Tang, Derrell R. Jackson (Appl. Phys. Lab., Univ. of Washington, Seattle, WA 98105, djtang@apl.washington.edu), Christopher Bassett, and Andone C. Lavery (Appl. Ocean Phys. and Eng., Woods Hole Oceanographic Inst., Woods Hole, MA)

High-frequency acoustic systems provide one of the potentially practical means for remote sensing of oil-in-ice. Sea ice is a complex medium that reflects, refracts, and scatters sound waves in complicated manner. The presence of oil adds additional complexity. A set of high-frequency acoustic data were taken at the Cold Regions Research and Environmental Laboratory (Hannover, NH) where crude oil was injected underneath artificial sea ice. A physics-based model is developed to interpret the data. The model consists of four layers to respectively describe the homogeneous half-space of water, the heterogeneous oil layer under ice, a thin skeletal ice layer, and a thick layer for the body of ice. The skeletal layer is allowed to have very different properties from the body of ice. All the interfaces at the boundaries of the layers are assumed rough. The model predicts scattered sound intensity in the time domain. Model results are discussed when it is applied to the acoustics data taken at both normal and 20-degree oblique incidence angles. The utility and the applicability of the model to actual arctic environments are anticipated.

4:00

1pAO11. Modeling thermal fracturing of sea ice, a historical view. Peter J. Stein (Sci. Solutions, Inc., 99 Perimeter Rd., Nashua, NH 03063, pstein@scisol.com)

Thermal fracturing of sea ice is an important mechanism not only for ambient noise generation, but also for climate change studies. It is possible that thermal fracturing is a fundamental mechanism behind the weakening of first and multiyear ice. During the late 1980s and early 1990s, a significant effort was conducted to model and measure the thermal fracturing of sea ice by the author and Dr. James K. Lewis. Here, we take a look back at that effort in the broader context of Arctic Ocean ambient noise and climate change.

4:15

1pAO12. Ambient noise in the Arctic Ocean measured with a drifting vertical line array. Peter F. Worcester, Matthew A. Dzieciuch (Scripps Inst. of Oceanogr., Univ. of California, San Diego, 9500 Gilman Dr., 0225, La Jolla, CA 92093-0225, pworcester@ucsd.edu), and John A. Colosi (Naval Postgrad. School, Monterey, CA)

In mid-April 2013, a Distributed Vertical Line Array (DVLA) with 22 hydrophone modules over a 600-m aperture immediately below the subsurface float was moored near the North Pole. The mooring parted just above the anchor shortly after deployment and subsequently drifted slowly south toward Fram Strait until it was recovered in mid-September 2013. The DVLA recorded low-frequency ambient noise (1953.125 samples per second) for 108 minutes six days per week. Previously reported noise levels in the Arctic are highly variable, with periods of low noise when the wind is low and the ice is stable and periods of high noise associated with pressure ridging. The median noise level at 98 m depth during the first two weeks of May not far from the North Pole had a maximum between 10 and 20 Hz of approximately 75 dB re 1 μPa^2/Hz. The background noise levels are at times extraordinarily low, with the 10th percentile over a 108-minute period limited by the self-noise of the hydrophones above approximately 100 Hz (35 and 26 dB re 1 μPa^2/Hz at 100 and 1000 Hz, respectively). During this time, the median ambient noise levels increased with depth by roughly 3 dB between 100 and 600 m.

4:30

1pAO13. Mid-frequency attenuation estimates from deep-water experiments using eigenrays. Jit Sarkar, Christopher M. Verlinden, Jefferey D. Tippmann, William S. Hodgkiss, and William A. Kuperman (Marine Physical Lab., Scripps Inst. of Oceanogr., Univ. of California, San Diego, 9500 Gilman Dr., Mail Code 0238, La Jolla, CA 92093-0238, bsarkar@ucsd.edu)

A collection of deep-water experiments were recently performed using a short vertical array cut for 7.5 kHz and a source transmitting tonals as well as chirps. Eigenray arrivals out to the first convergence zone were identified through matching the processed data to ray-tracing models, using environmental parameters measured during the experiments. The ray path and transmission loss information were used to produce an ocean-average attenuation result, and compared to decades-old attenuation models. Attempts were made at producing a layered estimate of attenuation using the experimental-simulation ray-matching — a technique previously proposed for inverting for ocean acidity. We present our ocean-average mid-frequency attenuation estimates, and our initial results for a layered attenuation inversion.

4:45

1pAO14. Long-term measurements of the directionality and active intensity of the underwater noise field in the shallow Beaufort Sea. Aaron Thode (SIO, UCSD, 9500 Gilman Dr., MC 0238, La Jolla, CA 92093-0238, athode@ucsd.edu), Susanna Blackwell (Greeneridge Sci., Santa Barbara, CA), Kerri Seger (SIO, UCSD, La Jolla, CA), and Katherine Kim (Greeneridge Sci., Santa Barbara, CA)

In each of the past seven years, at least 35 Directional Autonomous Seafloor Acoustic Recorders (DASARs) have been deployed over a 280 km swath of the Beaufort Sea continental shelf (20–55 m depth) during the open-water season to monitor the westward bowhead whale migration. DASARs have one omnidirectional pressure sensor and two orthogonal particle velocity sensors that permit measurements of the azimuths of both transient and continuous sounds, including diffuse ocean noise. Here, we map the azimuthal directionality of the Beaufort ambient noise field as a function of frequency and location across all seven seasons. Dominant directionalities exist in the diffuse ambient noise field, which change with frequency, time, and location. We examine how localized storms, heavy whale calling activity, seismic exploration, and other industrial activities influence the noise directionality. We also examine how both the active and reactive intensity of the noise evolves with frequency and time, by comparing the phase relationships between pressure and particle velocity. The directionality and active intensity help identify source mechanisms and help determine whether long-term changes in the ambient noise environment are occurring. [Work sponsored by the Shell Exploration and Production Company.]

Session 1pBA

Biomedical Acoustics: Medical Ultrasound and Imaging

Siddartha Sikdar, Chair
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Contributed Papers

1:30

1pBA1. High-frequency ultrasound of histology mimicking phantoms for evaluating breast cancer surgical margins. Nicole Cowan (Biotechnology, Utah Valley Univ., 800 W. University Parkway, MS 179, Orem, UT 84058-5999, ncowan18@gmail.com), Zachary A. Coffman (Biology, Utah Valley Univ., Orem, UT), Robyn K. Omer (Botany, Utah Valley Univ., Orem, UT), and Timothy E. Doyle (Phys., Utah Valley Univ., Orem, UT)

The ability to differentiate between malignant and normal tissues in surgical margins during breast cancer surgery would reduce the risk of local recurrence and subsequent surgeries. Clinical studies at the Huntsman Cancer Institute show that high-frequency (HF) ultrasound (20–80 MHz), and the parameters peak density (number of spectral peaks and valleys in the 20–80 MHz range) and attenuation, are sensitive to breast tissue pathology. The objective of this study was to determine the effect of tissue microstructure on these parameters using histology mimicking phantoms. Phantoms were created from distilled water, agarose powder, 10X TBE stock solution, and polyethylene microspheres to simulate breast tissue histology. Microsphere size (59–925μm diameter) and weight percent (0.00–0.06g) were varied in the experiments. Pitch-catch measurements were acquired using 50-MHz transducers, a HF pulser-receiver, a 1-GHz digital oscilloscope, and glycerol as the coupling agent. Both peak density and attenuation showed sensitivity to microsphere diameter and the number of scatterers present. Peak density followed an inverse-size relationship to microsphere diameter, whereas attenuation showed a sensitivity to the total weight percent of scatterers. The phantom results confirm that peak density and attenuation are complementary parameters for characterizing breast tissue pathology and validate the clinical studies.

1:45

1pBA2. Measuring the cytoskeletal properties of cell cultures using high-frequency ultrasound. Ashley Behan (Biology, Utah Valley Univ., 800 W. University Parkway, MS 179, Orem, UT 84058-5999, ashleyrosales92@gmail.com), Caitlin Carter (Biotechnology, Utah Valley Univ., Orem, UT), Amy A. LaFond, Dolly A. Sanjinez, Mandy H. Marvel (Biology, Utah Valley Univ., Orem, UT), and Timothy E. Doyle (Phys., Utah Valley Univ., Orem, UT)

High-frequency ultrasound (10–100 MHz) has been demonstrated to be sensitive to cell cytoskeletal changes. Cytoskeletal properties determine the biomechanical characteristics of cells and their role in many biomolecular processes. Examples include the aggressiveness and metastatic potential of breast cancer subtypes, T-cell activation during immune responses, and microtubule disintegration in Alzheimer's disease. The objectives of this work were to optimize the use of high-frequency ultrasound to subtype breast cancer cells and to acoustically measure cytoskeletal modifications. Pulse-echo measurements of 7 breast cancer cell lines of different molecular subtypes were acquired over a 2.5-year period using a 50-MHz transducer immersed in the growth media of monolayer cell cultures. Cell reflections were isolated from the interfering cell-culture plate reflections, spectrally analyzed using Gaussian curve fits, and spectrally classified using a heat map. The heat map displayed distinct patterns that differentiated the cell lines by molecular subtype. Cell cultures were also treated with colchicine and sphingosylphosphorylcholine to observe modulation of the microtubule and actin components. Cell waveforms and spectra displayed time-dependent changes due to chemical modification of the cytoskeleton. These results further verify and improve the noninvasive use of high-frequency ultrasound to differentiate breast cancer subtypes and to monitor cytoskeletal alterations in real time.

2:00

1pBA3. High-frequency ultrasound for rapid detection of skin cancer and other pathologies: Studies on porcine tissue. Benjamin F. Finch, James P. Pacheco (Biology, Utah Valley Univ., 800 W. University Parkway, MS 179, Orem, UT 84058-5999, benjaminfinchmed@gmail.com), and Timothy E. Doyle (Phys., Utah Valley Univ., Orem, UT)

The Breast Cancer Research Laboratory at Utah Valley University has been developing high-frequency (HF) ultrasound (20–80 MHz) to differentiate between malignant and benign tissues. Results from our breast cancer clinical trials thus far are promising, with high sensitivities and specificities. The objective of this study was to determine whether HF ultrasound can provide pathology sensitive measurements for diagnosing skin cancer and distinguishing between tissue structures. Formalin-preserved porcine tissues were first used to test the feasibility of the approach. The results show that both spectral peak density and wave velocity were sensitive to structure, and that normal skin tissue was significantly discernible from other tissues. An 80-patient clinical study is currently being conducted at the Huntsman Cancer Institute with the collection of ultrasonic measurements from at least 320 skin biopsies. Multiple pulse-echo and through-transmission measurements are acquired from each biopsy specimen. The ultrasound data are correlated to conventional pathology to determine sensitivity and specificity. If successful, HF ultrasound may provide an earlier diagnosis of skin cancer and a rapid, intraoperative method for differentiating between melanoma and benign pathologies. By improving on current methods, HF ultrasound may provide dermatologists with faster and more accurate results, and thus better patient treatment and outcomes.

2:15

1pBA4. High-frequency ultrasound (20–80 MHz) for analyzing breast cancer surgical margins: A 73-patient clinical study. Amy A. LaFond (Biology, Utah Valley Univ., 800 W. University Parkway, MS 179, Orem, UT 84058-5999, fairbrother.aa@gmail.com), Caitlin Carter (Biotechnology, Utah Valley Univ., Orem, UT), Robyn K. Omer (Botany, Utah Valley Univ., Orem, UT), Rachel E. Factor (Pathology, Univ. of Utah, Salt Lake City, UT), Leigh A. Neumayer (Surgery, Univ. of Arizona, Tucson, AZ), and Timothy E. Doyle (Physics, Utah Valley Univ., Orem, UT)

Results from a 2010 pilot study indicate that the peak densities of high-frequency (HF) ultrasonic spectra (20–80 MHz) correlate to a wide range of margin pathologies from breast conservation surgery (BCS). Utah Valley University and the Huntsman Cancer Institute conducted a follow-up study to determine the sensitivity and specificity of HF ultrasound for differentiating malignant from nonmalignant tissue in BCS margins. A 73-patient blind study was performed with conventional pathology used as the gold standard.

A total of 492 specimens were ultrasonically tested *ex vivo* and then sent to pathology for analysis. The margins were approximately 3x20x20 mm, with each sampled at 2–5 locations. The data were analyzed for malignancy using peak density. Results from the current study indicate that peak density can differentiate malignant from nonmalignant pathologies with an accuracy of 73.8%. Trends from the pilot study closely resemble this study's results. Application of these trends to the current study predicts that a multivariate analysis will yield much higher accuracy (84.1%), specificity (85.2%), and sensitivity (77.6%) values. The results show that HF ultrasound can provide rapid, intraoperative evaluation of surgical margins, thereby increasing the quality and efficacy of breast cancer surgery. [Funding provided by the Elsa U. Pardee Foundation.]

2:30

1pBA5. High-frequency ultrasound for evaluating margins during breast conservation surgery: Results from a 17-patient pilot study. Robyn K. Omer (Botany, Utah Valley Univ., 800 W. University Parkway, MS 179, Orem, UT 84058-5999, robynkiraomer@gmail.com), Kristina M. Sorensen (Mathematics, Pennsylvania State College, State College, PA), Leigh A. Neumayer (Surgery, Univ. of Arizona, Tucson, AZ), Rachel E. Factor (Pathology, Univ. of Utah, Salt Lake City, UT), and Timothy E. Doyle (Physics, Utah Valley Univ., Orem, UT)

Obtaining negative (cancer-free) margins in breast conservation surgery (BCS) is essential for ensuring all of the cancer has been removed from the excision site. Several rapid, noninvasive cancer detection methods are therefore being investigated for the intraoperative evaluation of margin status. This study investigated high-frequency (HF) ultrasound (20–80 MHz) as an intraoperative margin evaluation technique during BCS. In a 17-patient pilot study at the Huntsman Cancer Institute, Salt Lake City, Utah, through-transmission and pulse-echo measurements were acquired from 53 positions on specimens including margins, tumors, lymph nodes, and fibroadenomas. Measurements were acquired with the use of two 50-MHz transducers, a HF square-wave pulser/receiver, a 500-MHz digital oscilloscope, and a notebook PC. Parameters calculated from the data included peak density (the number of peaks and valleys across the ultrasonic spectrum), attenuation, and the slope of the second Fourier transform. Statistical analysis of the data revealed that a multivariate analysis combining peak density and attenuation provided the highest accuracy and sensitivity for differentiating malignant from nonmalignant tissue. The multivariate analysis showed 81.1% accuracy, 76.9% sensitivity, and 85.2% specificity. The results demonstrate that HF ultrasound is competitive with 2D specimen mammography and radiofrequency spectroscopy for margin evaluations. [Funding provided by Utah Valley University.]

2:45

1pBA6. A compensation method of frequency-dependent attenuation for pulsed Doppler systems by adapting the transmitting waveform. Jun Nishimura, Yu Teshima, Shizuko Hiryu, and Iwaki Akiyama (Life and Medical Sci., Doshisha Univ., 202-5 Kouridzuka, Kodo, Kyotanabe, Kyoto 6100310, Japan, dmo5001@mail4.doshisha.ac.jp)

Pulsed Doppler systems require a high signal-to-noise ratio (SNR) to differentiate the low amplitude of the blood flow echoes from the floor noise. Conventional quadrature demodulation (QDM) assumes that the central frequency of the emitted pulse is the same as the received echoes and uses this frequency as demodulation frequency. Nevertheless, the central frequency of the received echoes is actually downshifted due to the frequency-dependent attenuation (FRDA). This downshifting produces loss of SNR due to discarding energy of the down-mixed signal. In this study, by estimating the spectrum of a Gaussian modulated pulse, the downshift caused by the FRDA was obtained to create a new compensated pulse with the aim of forcing the echo central frequency to match with the demodulation frequency. The method was evaluated by using Field II simulation. Considering an attenuation of 0.5 dB/MHz/cm, a 5 MHz transducer and a relative bandwidth of approximately 50%, at a depth of 16 cm, compensated pulses reduced the frequency shift from 1.11 to 0.32 MHz and the SNR degradation from 9.25 to 0.41 dB. [This study was supported by the MEXT-Support Program for the Strategic Research Foundation at Private Universities, 2013–2017].

3:00

1pBA7. The effect of ambient pressure on the color Doppler ultrasound twinkling artifact. Julianna C. Simon, Bryan W. Cunitz (Ctr. for Industrial and Med. Ultrasound, Appl. Phys. Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, jcsimon@uw.edu), Oleg A. Sapozhnikov (Dept. of Acoust., Phys. Faculty, Moscow State Univ. Moscow, Russian Federation and Ctr. for Industrial and Med. Ultrasound, Appl. Phys. Lab., Univ. of Washington, Moscow, Russian Federation), Wayne Kreider (Ctr. for Industrial and Med. Ultrasound, Appl. Phys. Lab., Univ. of Washington, Seattle, WA), Jeffrey Thiel (Dept. of Radiology, Univ. of Washington Med. Ctr., Seattle, WA), James R. Holm (Ctr. for Hyperbaric Med., Virginia Mason Med. Ctr., Seattle, WA), Mathew D. Sorensen (Div. of Urology, Dept. of Veteran Affairs Med. Ctr., Seattle, WA), and Michael R. Bailey (Ctr. for Industrial and Med. Ultrasound, Appl. Phys. Lab., Univ. of Washington, Seattle, WA)

Recently, our group discovered that overpressure suppressed the color Doppler ultrasound twinkling artifact on *ex vivo* calcium oxalate monohydrate (COM) kidney stones, suggesting that trapped microbubbles on the stone surface cause twinkling (Lu *et al.* 2013). Yet the hypothesis is not fully accepted, partly because bubbles were not observed. Here, we extend the overpressure results to include under-pressure and use high-speed photography to visualize the bubbles. A programmable ultrasound system with Philips/ATL P4-2 transducer was used. *Ex vivo* COM stones were placed in a hydraulic pressure chamber and imaged acoustically through an acrylic window. The overpressure threshold to diminish twinkling was found to vary significantly, with twinkling eliminated at pressures of 3 ATA (atmospheres absolute) up to >8 ATA, even within the same stone. When the stones were exposed to 0.2 ATA (under-pressure), twinkling increased. High-speed photography during Doppler ultrasound revealed only one instance of an oscillating bubble. However, when stones were exposed repeatedly to a pre-focal, off-axis lithotripter pulse ($p_+ = 1.5$ MPa, $p_- = 2.5$ MPa), stones that twinkled had bubbles emerge from the same location with each pulse whereas stones that did not twinkle had a random bubble distribution. [Work supported by NSBRI through NASA NCC 9-58 and NIH DK043881, DK092197.]

3:15–3:30 Break

3:30

1pBA8. A new perspective for lung ultrasonography, preliminary results. Libertario Demi (Eindhoven Univ. of Technol., Den Dolech 2, Eindhoven 5612 AZ, Netherlands, l.demi@tue.nl), Wim van Hoeve (Tide Microfluidics, Enschede, Netherlands), Marcello Demi (Medical Imaging Processing, Fondazione Toscana Gabriele Monasterio, Pisa, Italy), Ruud J. van Sloun (Eindhoven Univ. of Technol., Eindhoven, Netherlands), Gino Soldati (Emergency Medicine Unit, Valle del Serchio General Hospital, Lucca, Italy), and Massimo Mischi (Eindhoven Univ. of Technol., Eindhoven, Netherlands)

Lung ultrasonography (LUS) is increasingly applied for the diagnosis of lung diseases. However, diagnoses are often based on imaging artifacts, e.g., B-lines, ultimately being qualitative and subjective. Aiming at gaining insight on the genesis of B-line artifacts, and on their link to the anatomical structures related to pathological conditions, dedicated lung-mimicking phantoms were manufactured and imaged with the ULA-OP research platform, proving access to raw radio-frequency (RF) data. To mimic a healthy and a diseased lung, two phantom types were made, being gelatin phantoms containing bubbly-layers composed of mono-disperse microbubble populations of different diameters: 140 and 80 μm, respectively. In fact, in various pathological conditions the size of the alveoli (air sacs composing the lung parenchyma), and hence the lung volume occupied by air, is alterated due to, e.g., fluid extravasation, alveolar collapse, and inflammation. Results show the appearance of B-lines only for phantoms designed to mimic pathological condition, confirming the link between artifact formation and reduction of air spaces dimensions. These preliminary results may be applicable to LUS, opening the way to the development of a quantitative ultrasound method dedicated to the lung.

3:45

1pBA9. Imaging of the femoral neck cortical bone based on iterative time domain topological energy. Chao Han, Didier Cassereau (Laboratoire d'Imagerie Biomédicale, Laboratoire d'Imagerie Biomédicale, Paris, France, chao.han@upmc.fr), Vincent Gibiat (Laboratoire PHASE, Toulouse, France), Jean-Gabriel Minonzio, Pascal Laugier, and Quentin Grimal (Laboratoire d'Imagerie Biomédicale, Paris, France)

Osteoporosis is a frequent bone disease that mainly affects women after menopause. It is characterized by a decrease in bone mass and a deterioration of the micro-architecture, which can lead to an increased risk of fracture. Ultrasound technologies provide an affordable mean to implement non invasive solutions to diagnostically assess the characteristics of the bone structure. In this work, we are interested in imaging the external and internal boundary of the cortical bone, and the evaluation of the thickness using the Time Domain Topological Energy (TDTE) method. These two properties are important to interpret the measurements of guided waves dispersion curves and predict the risk of osteoporosis and fracture. The iterative procedure of TDTE provides better performance in imaging the internal boundary of the cortical bone compared to the one-step TDTE. The barrier of implementing iterative TDTE is the requirements of huge storage during the numerical propagation step. A specific back-propagation strategy is implemented here to deal with this obstacle. The obtained results will be illustrated numerically and experimentally.

4:00

1pBA10. Development of complex tissue-mimicking phantoms for quantification of flow by the time-intensity method in contrast enhanced ultrasound imaging. Asawari Pawar, Gregory Clement, and Mark Howell (Biomedical Eng., Cleveland Clinic Foundation, Cleveland Clinic Foundation, Lerner Res. Inst., 2111 E 96TH St, Cleveland, OH 44106-2917, asawaripawar26@gmail.com)

Currently, there are few simple-to-construct *in vitro*, wall-less phantoms that have accurate acoustic properties while mimicking the complex normal and neoplastic geometries of the vascular network. The purpose of this study was to develop agar-based tissue-mimicking phantoms (TMP) to model such networks. Three types of vascular networks were considered: (1) single vessel, (2) multi-vessel with artery bifurcations, and (3) multi-vessel with artery bifurcations and structural abnormalities typical of diseased (tumor) vascular networks. Blood-flow related parameters were derived from the time-intensity curves obtained from the bolus injection of a lipid-based microbubble ultrasound contrast agent (UCA) under varying flow conditions relevant to our ongoing work in developing techniques to simultaneously quantify both the total volume and flow measurements within a tumor phantom. A Fukuda Denshi Ultrasound system was used with a linear probe (LG308-16A) positioned transversely and longitudinally to the direction of the flow. B-mode image acquisition was performed with 0.5 mL of UCA bolus injected into a 500 mL degassed water reservoir and then pumped through the vessels at rates ranging from 20 mL/min to 100 mL/min. Offline analysis of time-intensity curves in response to varied flow conditions indicated the TMP ability to yield easily reproducible simulations of vascular microcirculation.

4:15

1pBA11. Evaluating the robustness of an ultrasound based sensing strategy for intuitive control of upper extremity prosthetics. Nima Akhlaghi (Elec. and Comput. Eng., George Mason Univ., 4400 University Dr., Fairfax, VA 22030, nakhlagh@gmu.edu), Alex Baker (Bioengineering, George Mason Univ., Fairfax, VA), Huzefa J. Rangwala, Jana Kosecka (Comput. Sci., George Mason Univ., Fairfax, VA), and Siddhartha Sikdar (Bioengineering, George Mason Univ., Fairfax, VA)

Current commercially available prostheses based on myoelectric control have limited functionality, leading to many amputees abandoning use. Myoelectric control using surface electrodes has a number of limitations and lacks specificity for deep muscles, presenting a continued need for more robust strategies. We propose a new strategy for sensing muscle activity based on real-time ultrasound imaging. Results from our previous work demonstrate that complex motions could be classified with 92% accuracy in real-time. However, arm and hand repositioning during natural movements tend to alter the geometry of forearm musculature, possibly affecting performance. In this study, we evaluated the robustness of the image-based control strategy in the presence of varied forearm positions on able-bodied subjects. Ultrasound images of the forearm muscles were collected during two different scenarios using a Sonix RP with a 5–14 MHz linear probe. The subject was asked to perform four hand motions at eight different arm positions and three levels of wrist pronation. Images were analyzed to generate activity patterns for each motion and then classified. Results demonstrate that forearm positions do not significantly compromise reliability. We also show that performance could be further improved by including additional training activity patterns corresponding to motions performed in a few selected arm positions.

4:30

1pBA12. Kidney stone specific ultrasound imaging of human subjects. Bryan W. Cunitz, Barbrina L. Dunmire, Michael Bailey, Yasser Haider, Adam D. Maxwell, Julianna C. Simon (Ctr. for Industrial and Medical Ultrasound, Appl. Phys. Lab, Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, mike.bailey.apl@gmail.com), Jeff Thiel (Dept. of Radiology, Univ. of Washington School of Medicine, Seattle, WA), Oleg A. Sapozhnikov (Appl. Phys. Lab/Dept. of Acoust., Univ. of Washington/Moscow State Univ., Seattle, WA), Jonathan D. Harper, and Mathew D. Sorensen (Dept. of Urology, Univ. of Washington School of Medicine, Seattle, WA)

Sensitivity and specificity data show users have more difficulty in identifying stones accurately in B-mode ultrasound than x-ray CT. Our goal was to evaluate the signal to noise (SNR) of a new stone specific imaging algorithm, S-mode based on Color Doppler twinkling artifact, to B-mode. Forty sets of B- and S-mode imaging data were collected from 16 subjects using a Philips HDI C5-2 imaging probe and Verasonics ultrasound system. Two ways S-mode differs from Doppler is that it filters out blood flow signal and uses reverse color write priority to add color to echogenic regions only. For both B- and S-mode raw data, we calculate SNR of the magnitude (brightness) of the stone signal compared to the second highest magnitude in the image. The mean and standard deviation of the SNR was 1.6 ± 0.7 for B-mode and 37 ± 24 for S-mode, with 1 being the stone is equally bright as, and difficult to distinguish from, background. In this human study of S-mode, stones appeared over 30 times brighter than background and with over 20 times the contrast to background seen in B-mode. [Work supported by NIH NIDDK grants DK043881 and DK092197, and NSBRI through NASA NCC 9-58.]

4:45

1pBA13. Investigation of on skin surface response due to acoustic radiation from stenosed blood vessels. Huseyin Enes Salman and Yigit Yazicioglu (Mech. Eng. Dept., Middle East Tech. Univ., Orta Dogu Teknik Universitesi, Universiteler Mahallesi,, Dumlupinar Bulvari No:1, Cankaya, Ankara 06800, Turkey, salman@metu.edu.tr)

Arterial stenosis is a form of cardiovascular disease which leads to highest rate of fatalities worldwide. When stenosis is present in arteries feeding the heart, it leads to heart attack and often sudden death. If occlusion is present in arteries feeding brain, it causes stroke and rapid loss of brain functions. Arterial disease is usually not confined to critical organs such as the heart and the brain but observed throughout the peripheral cardiovascular system. Acoustic radiation due to stenosis propagates through soft tissues and reaches to skin surface. Therefore, these signals detected on skin surface may provide valuable information for diagnostic purposes. In this study, effects of acoustic radiation on skin surface due to a stenosis are investigated. Human upper arm is modeled using commercial finite element software ADINA. Realistic geometries and soft tissue mechanical properties are employed. Acoustic pressure distribution due to constriction is modeled using related studies in literature and applied on inner surface of blood vessel. Harmonic analysis is performed for upper arm and pressure distribution on skin surface is obtained. It is observed that increasing level of stenosis leads to an increase in pressure amplitudes on skin surface where the region which is closest to the constricted artery has the highest pressure amplitudes.

Session 1pNS

Noise and Animal Bioacoustics: Soundscape and Its Application

Brigitte Schulte-Fortkamp, Cochair
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Bennett M. Brooks, Cochair
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Chair's Introduction—1:00

Invited Papers

1:05

1pNS1. Standardization in soundscape and its application. Brigitte Schulte-Fortkamp (Inst. of Fluid Mech. and Eng. Acoust., TU Berlin, Einsteinufer 25, Berlin 101789, Germany, b.schulte-fortkamp@tu-berlin.de) and Bennett Brooks (BROOKS Acoust. CORP, Vernon, CT)

Since 2014, the first ISO Standard in Soundscape is on the market: IS0 12931-1, 2014 Acoustics — Soundscape — Part 1: Definition and conceptual framework. The Standard "explains factors relevant for measurement and reporting in soundscape studies, as well as for planning, design and management of soundscape." It is a first but big step to accept the idea that the perception of people has at least the same relevance as the physical measurements for the purposes of urban planning. Moreover, as sound is considered to be a resource and not a waste, the door is now open for designing our acoustic environment. The next step in this process is the development of ISO 12931-2 on methods and measurements, from which we will learn more about the character of holistic judgments. In addition, there is much new work on ANSI standards that consider life in park and wilderness areas. All of these engagements are directed to enhance the quality of life not only for humans but also for non-human beings. The paper will describe and discuss these different approaches.

1:25

1pNS2. Virtual acoustic environments for soundscape research and urban planning. Michael Vorlaender and Jonas Stienen (ITA, RWTH Aachen Univ., Kopernikusstr. 5, Aachen 52056, Germany, mvo@akustik.rwth-aachen.de)

The utilization of Virtual Reality technology offers fascinating perspectives for the assessment of urban environments regarding the comfort, well-being, feeling of safety, and public health. Such technology, if available with a user-friendly software interfaces to existing and future planning tools, will expand the planning process into an integrative approach. Apart from sound, this may also involve vision and other aspects such as air pollution or climate change. The future design outline of the buildings, city quarters, and cities up to megacities can be assessed by taking the different perceptual modalities into account in an integrative procedure. Facilitating Virtual Reality for future environments in the assessment of new urban projects enables the population to get involved and renders the procedure more ecologically valid. Thus, by inclusion of the population, large counterforces, even demonstrations, or citizen's initiatives against urban or transport development (e.g., current discussions about infrastructure, airports, railway line planning, and wind farms) could be avoided. Recent developments in Virtual Reality technology for the built environment are highlighted by focusing on acoustics and noise control but also integrating vision, climate change, and other aspects of the multimodal indoor and outdoor assessment of comfort.

1:45

1pNS3. Auditory meaningscapes—An ecological perspective on soundscape perception. Frederik L. Nielbo (Dept. of Aesthetics and Commun., Ctr. for Semiotics, Aarhus Univ., Nordre Ringgade 1, Aarhus 8000, Denmark, norfln@dac.au.dk)

As a semiotic resource, the soundscape carries information about events relevant to the perceiving organism. Throughout evolution, the auditory system has been shaped to detect, localize, and identify such significant events in the environment in order to initiate appropriate behavior. The sounds are, in other words, environmental sign vehicles to be picked up and utilized by the perceiving organism, allowing it to navigate in the surroundings, avoid potential dangers, etc. Far from being a passive receiver, the auditory system is an active semiotic tool for collecting information relevant for the given situation. From the rudimentary hearing system of simpler organisms to the complex human auditory system, perception of auditory events is functional and instrumental; it guides the perceiver's behavior by carrying information about potential interactions with the environment. A growing number of studies suggest that auditory perception is intimately coupled with action and that listeners' perception of soundscapes is structured around semantic categories related to events and activities taking place in the heard environment. Thus, I argue, to get a richer understanding of soundscapes, it is necessary to pay attention to the semiotic dynamics of the interaction between the perceiver and the sonic environment.

2:05

1pNS4. Soundscape response in animals. Susan M. Wiseman (Waco, TX, sw1210txstate@gmail.com)

The World Health Organization (WHO) has long warned against chronic or extreme noise exposure as it has been shown to impact humans, as have the U.S. Surgeon General and a variety of academic and health research studies. Little is known about safe sound levels for animals, let alone safe frequency exposure for specific species. Behavioral and physiological response has been noted in human and non-human animals, most obviously fright and flight in the face of major stimuli such as thunder or gunshots at one end of the spectrum, down to minute stimuli such as the rustle of a leaf indicating the proximity of prey or a predator. Some animals are attracted or deterred by certain sounds, some mimic, in agriculture some become more or less productive according to their soundscape. To improve animal welfare, the Association of Zoos and Aquariums requires the enrichment of captive environments with the goal of increasing an animal's behavioral choices and drawing out species-appropriate behavior. It has been noted that certain southern white rhinoceros *(Ceratotherium simum simum)* altered their behavior in response to a variety of sound stimuli, including music, illustrating how the soundscape can be manipulated as a tool for animal enrichment.

1p MON. PM

2:25

1pNS5. Patient centered method and soundscape—A bridge between clinicians and acousticians. Robert Y. McMurtry (Surgery, Schulich School of Medicine, Western Univ., 403 Main St., Picton, ON K0K2T0, Canada, rymcmurtry1@gmail.com)

The Patient Centered Method (PCM) and Soundscape have much in common including their emergence about 60 years ago based on the work of Balint and Kryter, respectively. Both place the patient or person at the center of management of clinical illness or noise annoyance. PCM requires that the patient perceive that they have experienced meaningful care, communication, and common ground in clinical encounters. The evaluation focuses on the patient's life context and their perception of disease or the "illness experience." When PCM is accomplished, the result is higher satisfaction, better outcomes of chronic diseases, fewer tests, and referrals and attendant lower costs (Stewart *et al*., 2000). Soundscape, a term coined by Shafer in 1977 also places the person in center, in the context of their acoustic environment, emphasizes their perception of noise as the "New Experts" (Bray 2012). According to Bray exposed people are "objective measuring instruments whose reports and experiences must be taken seriously and quantified by technical measurements." This paper will explore the congruence of PCM and Soundscape and the necessity of this approach in evaluating the experience of those exposed to wind turbine acoustical energy.

2:45

1pNS6. Acoustical impact of wind turbines on soundscape. Klaus Genuit, Andre Fiebig (HEAD Acoust. GmbH, Ebertstr. 30a, Herzogenrath, NRW 52134, Germany, Klaus.Genuit@head-acoustics.de), and Brigitte Schulte-Fortkamp (Tech. Univ. Berlin, Berlin, Germany)

It is well known that wind turbines have a negative impact on the landscape. But what is their impact on soundscape? Is this independent from the visual perception? Increasing research efforts are made to explain annoyance and complaints caused by wind turbines in detail, but still several questions are unanswered. The acoustical contribution of wind turbines depends on the technical design of the generator and of the blades. All of them produce low frequencies; some of them produce noise in the middle and higher frequencies with tones and modulations. It is clear that the A-weighted sound pressure level is not the appropriate indicator to predict resulting annoyance. The question is what must be considered to understand the perceived sound quality within the context of soundscape? Are psycho-acoustical parameters able to describe the sound character of wind turbines in a better way? To get an improved understanding of the complex interactions of the sound produced by wind turbines and the existing sounds of a given soundscape basic studies were performed and the results will be presented.

3:05–3:20 Break

3:20

1pNS7. Soundscape of a wind farm—The Cape Bridgewater experience. Steven E. Cooper (The Acoust. Group, 22 Fred St., Lilyfield, NSW 2040, Namibia, drnoise@acoustics.com.au)

The general concept for describing the noise environment in proximity to a wind farm is expressed in terms of the A-weighted level that will vary dependent upon the wind strength. The compliance methodology in general use for wind farms relies upon a measurement that includes wind and an average line of fit through such data. Measurements at residential receivers when conducted using full spectrum recording/analysis revealed unique characteristics extending into the infrasound region that are normally inaudible that would appear to be present when disturbance is noted. There are no traditional dose-response investigations for the full spectrum of wind farm noise on which to describe the soundscape. A new approach to assessing wind farm noise emissions was used for the Cape Bridgewater wind farm study identifying different concepts for describing the soundscape of the wind farm

3:40

1pNS8. Uses of soundwalks in computer modeling of soundscapes during the design process. Gary W. Siebein, Marylin Roa, Gary W. Siebein, Hyun G. Paek, and Paul C. Jones (Siebein Assoc., Inc., 625 NW 60th St., Ste. C, Gainesville, FL 32607, gsiebein@siebeinacoustic.com)

This paper presents a case study of the use of soundwalks to gather data for computer simulations of complex soundscapes while they are being designed. A soundwalk is a process where people enter an existing soundscape for listening, observation, measurement, recording or evaluation. This project is for a new mixed use urban center. Studies were undertaken to investigate the soundscape of this new community both within the community itself as well as outside the community while it was being designed. Soundwalks were taken through existing communities with similar buildings, urban spaces and infrastructure to those being proposed in the design. Acoustical measurements made during the soundwalks of specific acoustic events that occurred in the communities were used as input data for

sound sources in a large, three dimensional computer model of the site and its environs. The model was used to estimate future sound levels from the mix of activities in the new community. Aural recordings of the specific acoustic events were used in aural simulations of the spaces where stakeholders could evaluate the acoustical conditions in the community and provide insights into the design of the soundscape.

Contributed Papers

4:00

1pNS9. Water soundscape and listening impression. Yosua W. Tedja and Lucky Tsaih (Architecture, National Taiwan Univ. of Sci. and Technol., RB-807, No.43, Sec. 4, Keelung Rd., Da'an Dist., Taipei 10607, Taiwan, yosua_wiranata@yahoo.co.id)

This paper presents the preference of water soundscape through listening evaluation. As meditation, listening to water sound is a tool that often use to provide positive emotion and psychological restoration. Twenty water soundscape samples were chosen based on natural and man-made sounds, as well as the sound in relation to the architecture and materiality. A semantic differential questionnaire was created with nine pairs of contractual sound qualities. Sixty-six architectural students with normal hearing condition were participated in this listening evaluation. The result has shown that 92% of the participants have positive impression to a soft quiet mid frequency sound (gentle stream) due to the listening impression of relax (88%) and comfort (89%) qualities. On the contrary, 77% of the participants have a negative impression for a loud intense broadband sound (rain on glass roof) due to the listening impression of noisy (82%) and agitating (80%) qualities. Sixty-two percent of the participants prefer rain on water sound due to the listening impression of comfort (60%) more than rain on different materials such as woods, metal, glass, tent, and pavement. Shishiodoshi and Suikinkutsu were also identified with "quiet" sound quality but overall likely impression is not as high as water fountain.

4:15

1pNS10. Comparison of urban and rural soundscapes associated with *Dumetella carolinensis* and *Cardinalis cardinals*. David P. Knobles (Knobles Sci. Applications LLC, PO Box 27200, Austin, TX 78755, dpknobles@yahoo.com), Mohsen Badiey (College of Earth, Ocean, and Environment, Univ. of Delaware, Newark, Delaware, DE), and Preston S. Wilson (Dept. of Mech. Eng., Univ. of Texas at Austin, Austin, TX)

Both the acoustic transmission properties of the environment and the ambient noise field are factors that affect avian soundscapes. Long-term acoustic measurements made with Song Meter SM2+ recorders in both Texas and Delaware are analyzed for the information they contain on soundscapes as they pertain to songbirds, such as *Dumetella carolinensis*, commonly found in Delaware, and *Cardinalis cardinals*, common to both Delaware and Texas. The measurements in both states are made in both urban and rural environments and in coincidence with physical measurements of temperature, humidity, wind speed, and direction. Additional acoustical measurements are made with other sound recorders to gain more specific information about, for example, the dawn chorus. The efficacy of using the characteristics of the chorus as an indicator of the health of the avian soundscape is discussed. Band limited cross-correlation methods are used to test various hypotheses on bird communication and behavior.

4:30

1pNS11. What do hedonic studies of the costs of road traffic noise nuisance tell us? Abigail Bristow (School of Civil and Bldg. Eng., Loughborough University, Loughborough LE11 3TU, United Kingdom, a.l.bristow@lboro.ac.uk) and Sotirios Thanos (Univ. College London, London, United Kingdom)

The value or cost of noise nuisance is important as it enables judgments to be made on the costs and benefits of interventions. This paper presents a review and meta-analysis of hedonic pricing (HP) studies of road traffic noise nuisance. Noise nuisance has commonly been valued using HP, a revealed preference approach based on the housing market, where house price is a function of a myriad of characteristics of the house and the surrounding area including noise. The value of noise obtained is expressed as the percentage change in house prices that results from a 1 decibel (dB) change in noise levels (Noise Depreciation Index, NDI). The approach is broadly accepted and underpins most values used in Government transport appraisals. However, the range of values is large, from 0.08 to 2.21 NDI according to the last review of the literature in 2001. This paper examines available studies to shed light on the variation in noise values, as well as new methodological developments, such as the widespread use of spatial econometrics and addressing non-linearities of noise values.

4:45

1pNS12. Implementation of an augmented reality interface to reproduce and compare soundscapes. Philip W. Robinson (Specialist Modelling Group, Foster + Partners, 22 Hester Rd., London SW11 4AN, United Kingdom, philrob22@gmail.com)

Soundscape design is a growing concern in architectural practice; yet, conveying soundscape properties is a challenge. Quantitative measures like decibel levels offer little utility; birdsong and squealing brakes may be at the same frequency and level, yet one is obviously preferable. Furthermore, visual qualities of the scene have a substantial effect on perception of the acoustic environment. To improve communication between acoustic designers, architects, and clients, an augmented reality interface has been designed to allow comparisons of soundscapes and their relationships to the built environment. The interface consists of a physical scale model, printed data, and a tablet application. The augmented reality application uses a machine vision algorithm to recognize the model and allow on-screen interaction. On the tablet, measurement points are displayed on a live image of the model at their respective locations, and the user may select a point by touch, which will begin sound playback and display an immersive image of the scene. The participant can then look around a spherical image of the scene using the tablet as a movable window, and thereby listen to the environment with appropriate accompanying visual cues. The interface has been a useful tool to communicate urban sound issues.

5:00

1pNS13. Residents' sound preference of rural soundscape in China. Xinxin Ren (School of Architecture, Harbin Inst. of Technol., 66 Xida Zhi St., Nangang District, Harbin 150006, China, xinxin088521@126.com), Jian Kang (School of Architecture, Harbin Inst. of Technol., Sheffield, United Kingdom), and Hong Jin (School of Architecture, Harbin Inst. of Technol., Harbin, China)

The importance of rural soundscape has been recently recognized for the recreational and amenity value, where man-made noise is at a low level and the dominance of natural sounds promotes sound preference, but there is a lack of studies on the sound preference of residents in the villages of China, which are undergoing a fast development in urbanization. In this study, a questionnaire survey was undertaken at 36 villages of northeast regions, representing all major soundscape types. The results show that among the individual factors, age, education level, and landscape environment are more significant than the factor of gender, in terms of influence on sound preference. With increasing age, the sound preference of traffic and mechanical sound has a tendency of increase and then decrease, whereas the tendency for human voice, natural, and melody sound is opposite. With a higher education level, the sound preference of traffic, mechanical sound, and human voice decreases, and on the contrary, sound preference for natural and melody sound increases. However, the evaluation of natural and melody sound is lower in better landscape environment, which is perhaps due to the residents' higher requirements in soundscapes corresponding to the landscapes.

5:15–5:35 Panel Discussion

Session 1pPA

Physical Acoustics, Structural Acoustics and Vibration, and Engineering Acoustics: Phononic Metamaterials II

Joel Mobley, Chair
Physics and Astronomy, University of Mississippi, PO Box 1848, 1034 NCPA, University, MS 38677

Contributed Papers

1:00

1pPA1. Expanding the low frequency transparency band of shell structures for sonic crystals. Alexey S. Titovich (Naval Surface Warfare Ctr., Carderock Div., 9500 MacArthur Blvd., West Bethesda, MD 20817, alexey.titovich@navy.mil), Andrew N. Norris (Mech. and Aerosp. Eng., Rutgers Univ., Piscataway, MD), and Stephen D. O'Regan (Naval Surface Warfare Ctr., Carderock Div., West Bethesda, MD)

Elastic cylindrical shells are often used as the elements of sonic crystals for wave steering applications. The thickness-to-radius ratio of the shell determines its quasi-static acoustic properties: effective bulk modulus and density. Matching the bulk modulus to that of the surrounding fluid removes the monopole response, while matching the density removes the dipole response. Together, they yield a low frequency band in which the shell is acoustically transparent. In this study, we look to broaden the transparency band by removing the quadrupole response as well. Among other methods, we will investigate the potential for two nested, counter-vibrating, shells to control quadrupole radiation.

1:15

1pPA2. Propagation of pulsed ultrasonic fields in a band gap of a two dimensional phononic crystal. Ukesh Koju and Joel Mobley (Phys. and Astronomy, Univ. of MS, 145 Hill Dr., P.O. Box 1848, University, MS 38677, ukoju@go.olemiss.edu)

A band gap in the transmission spectrum of a finite two dimensional phononic crystal is examined in the time domain using pulsed ultrasonic fields. The phononic crystal consists of a hexagonal array of copper cylinders (r = 1.19 mm) in an aqueous matrix with a lattice constant of 2.9 mm. Measurements of the transmission properties of the sample are performed using ultrasonic wave groups of various center frequencies and bandwidths. Among the band gaps in the low-MHz range, we concentrate on the gap from 1.48 MHz—1.70 MHz. The phase velocity, group velocity, and attenuation coefficient spectra are determined and compared with expectations.

1:30

1pPA3. Acoustic scattering cancelation in an aqueous environment using phononic crystals. Matthew D. Guild (NRC Res. Associateship Program, Naval Res. Lab, Washington, DC), Theodore Martin (Naval Res. Lab, 4555 Overlook Ave. SW, Washington, DC 20375, theodore.martin@nrl.navy.mil), Charles Rohde, David Calvo, and Gregory Orris (NRC Res. Associateship Program, Naval Res. Lab, Washington, DC)

Acoustic scattering cancelation is an approach that enables the elimination of the scattered field from an object within the surrounding medium. While this cancelation effect can be achieved through the use of a single, isotropic fluid, such a simple design limits its application to objects that are small compared to a wavelength. More complicated multilayered fluidic coatings are necessary for the cancellation of higher order scattering modes. Such modes arise from objects with characteristic lengths comparable to the incident wavelength in the surrounding medium. To realize such a coating, phononic crystals offer a means for precisely designing the necessary structures. In this work, analytical and numerical results will be presented for the acoustic scattering cancellation of cylindrical objects in an aqueous environment using multilayered effective fluid coatings constructed of phononic crystals. [Work supported by the Office of Naval Research and the National Research Council.]

1:45

1pPA4. Negative refraction of acoustic waves in phononic crystals using recursive algorithms for block toeplitz matrices. Feruza A. Amirkulova (Phys. and Astronomy, Vassar College, 124 Raymond Ave., Poughkeepsie, NY 12604, feamirkulova@vassar.edu) and Andrew N. Norris (Mech. and Aerosp. Eng., Rutgers Univ., Piscataway, NJ)

Recent improvements in design and manufacturing have significantly improved our ability to manage phononic crystals (PC). Researchers have been studied the negative refraction in PC experimentally and theoretically using multiple scattering (MS) theory. This problem requires solving a large complex valued linear system that has a special multilevel block Toeplitz (BT) structure. We study negative refraction of acoustic waves in 2D PC by means of MS theory, by taking advantage of the PC structure and using specific recursive algorithms for BT matrices. We present new efficient and accurate algorithms for solving acoustic MS problem by the cluster of closely spaced cylinders to design acoustic negative refraction imaging in a PC. The unit cell of the PC consists, in general, of a solid cylinder in an acoustic medium. The dispersion curves of PC have a negative refraction dispersion branch producing the focusing effect. Particular attention is given to the dynamic behavior in the vicinity of dispersion branches with negative slope, and to the band gaps. We explore the effect of focal point on structural parameters, and employ a parallelization technique that allows efficient application of the proposed recursive algorithms for solving BT systems on high performance computer clusters. Numerical comparisons of CPU time and total elapsed time taken to solve the linear system using the direct LAPACK and TOEPLITZ libraries on Intel FORTRAN show the advantage of high performance recursive algorithms over the Gaussian elimination.

2:00

1pPA5. Acoustic phase hologram with labyrinthine metamaterials. Yangbo Xie (Elec. and Comput. Eng., Duke Univ., 3417 CIEMAS, Durham, NC 27705, yx35@duke.edu), Chen Shen, Yun Jing (Mech. and Aerosp. Eng., North Carolina State Univ., Raleigh, NC), and Steven Cummer (Elec. and Comput. Eng., Duke Univ., Durham, NC)

Acoustic metamaterials offer large degree of design freedom and precise control over amplitude and phase at subwavelength scales. In the past, we have demonstrated a family of labyrinthine metamaterial unit cells as premium building blocks for phase modulation devices, as well as several 1D wavefront shaping devices based on these unit cells. Here we extend the complex modulations to 2D by demonstrating a computer generated metamaterial-based phase hologram. Through spatially modulating the phase of the wavefront, the hologram projects the incident wave to a designed three-dimensional amplitude pattern. The hologram is designed with a two-step

process: first, an iterative holographic reconstruction algorithm is used to obtain the optimal phase pattern of the hologram; second, unit cells with desired phase modulations are designed and fabricated. Ray tracing and full-wave simulations have been performed to verify the design. The measurements of reconstruction in an anechoic chamber will be taken for a hologram designed to operate around 4 kHz. The metamaterial-based hologram creates a three-dimensional acoustic illusion with only passive structures. The designing process can also be extended to devices such as multi-focal lenses and wave-based analog processing/computing interfaces.

2:15

1pPA6. Metascreen-based acoustic passive phased array with subwavelength resolution. Likun Zhang (The Univ. of Texas at Austin, 2515 Speedway, Stop C1610, Austin, TX 78712-1199, lzhang@chaos.utexas.edu), Yong Li (CNRS-Université de Lorraine, Vandœuvre-lés-Nancy, France), Xue Jiang, Bin Liang, and Jian-chun Cheng (Nanjing Univ., Nanjing, China)

A phased source array is an array consisting of elementary sources with proper relative phases to steer a wavefront, so as to form desired wave fields of specific property and applications. However, the phased array requires a large number of sources in forming complex wavefront or non-paraxial wave beams, leading to high cost and complexity in the electronics required to operate individual sources of the active array. A passive metascreen is presented here to transmit sound energy from a single source and steer the transmitted wavefront to form desired fields. The metascreen plays a role like a phased array but with a passive way that avoids the complexity of an active array. The screen has a half-wavelength thickness and composes of a series of elements with a dimension of one-tenth of the sound wavelength along the screen. The elements have a hybrid structure designed for high transmission and full range of phase shift. The performance of the screen is numerically simulated and experimentally demonstrated to generate a self-bending beam in non-paraxial region. The screen with its simple configuration and extreme acoustic performance could have applications for sound field shaping in numerous areas where the conventional array would have complexity and limited capability.

2:30

1pPA7. Subwavelength acoustic metamaterial with tunable acoustic absorption. Nicolas Viard, Cali Gallardo, Jun Xu, and Nicholas Fang (Mech. Eng., Massachusetts Inst. of Technol., 77 Massachusetts Ave., Cambridge, MA 02139, nviard@mit.edu)

We present numerical simulations and experimental measurements for ultrasonic transmission through a subwavelength metamaterial consisting of an array of hollow cylinders embedded in a soft elastic matrix. The mechanical properties of the matrix, the lattice constant, and the size of the cylinders are optimized in order to maximize sound absorption in the metamaterial while the cylinders are filled with air. The acoustic transmission is restored when the cylinders are filled with water. Our design expands the concept of metamaterial as it demonstrates the ability to tune the acoustic properties of a subwavelength material.

2:45

1pPA8. Rotating the directivity of sound radiation by acoustic metastructures. Likun Zhang (Dept. of Phys. and Ctr. for Nonlinear Dynam., The Univ. of Texas at Austin, 2515 Speedway, Stop C1610, Austin, TX 78712-1199, lzhang@chaos.utexas.edu), Xue Jiang, Bin Liang, Xin-ye Zou, and Jian-chun Cheng (Key Lab. of Modern Acoust., MOE, Inst. of Acoust., and Collaborative Innovation Ctr. of Adv. Microstructures, Nanjing Univ., Nanjing, China)

Radiation directivity is an important measure of sound fields radiated from acoustic sources. Manipulation of the directivity plays a significant role in many situations ranging from audio and auditorium acoustics to medical ultrasound applications. An acoustic meta-structure is presented here to rotate the directivity of sound radiation from sources surrounded by the meta-structure with an anisotropic acoustic property. The meta-structure consists of an array of platelets, regularly arranged in several concentric rings. The platelets' orientation is determined from transformation acoustics model. Numerical simulations of sound fields with the structure reveal that the angle of sound directivity rotated by the structure is independent of sound frequency and source location. The rotation is verified through experimental measurements with the meta-structure fabricated by thermoplastics materials via 3D printing. The rotation angle varies over a broad range through tuning geometry parameters of the meta-structure. The meta-structure with its extreme performance can hence provide various applications in the effective control of radiation directivity in acoustic engineering.

Session 1pSP

Signal Processing in Acoustics, Underwater Acoustics, and Acoustical Oceanography: Direction of Arrival (DOA) Estimation, Source Localization, Classification, and Tracking Using Small Aperture Arrays II

Geoffrey H. Goldman, Cochair
U.S. Army Research Laboratory, 2800 Powder Mill Road, Adelphi, MD 20783-1197

R. Lee Culver, Cochair
ARL, Penn State University, PO Box 30, State College, PA 16804

Invited Paper

1:30

1pSP1. Tomographic sonar image formation of difficult objects and of mines on the seabed. Brian G. Ferguson (DSTO, PO Box 44, Pyrmont, NSW 2009, Australia, Brian.Ferguson@dsto.defence.gov.au) and Ron J. Wyber (Midspar Systems, Oyster Bay, NSW, Australia)

Insonifying a sea mine over a complete (360°) set of look directions, while recording the acoustic returns (or echoes) from the object as a function of aspect angle, enables the two dimensional projection data (or measurement) space to be fully populated. An acoustic image is readily reconstructed by applying Fourier transform methods to the projection data. Tomographic sonar images of various (inert) sea mines are presented, where a fixed monostatic sonar insonifies the object as it rotates about its vertical axis through one complete revolution. A difficulty arises if the specular component returned from one part of the object swamps the returns from the rest of the object. The problem is solved by taking spatial derivatives of the Fourier reconstructed image, which then results in a representation that enables the object to be recognized. Another complication presents itself when structural waves, which are excited by the insonification process, contribute to the observed impulse response. Numerous examples of the effect of these structural waves on the formation of the image are presented for various objects and sonar technologies, including parametric sonar. For operational tomography, the object is fixed (a mine resting on the sea floor), which requires the sonar to circumnavigate the mine (at a safe standoff distance) while simultaneously insonifying it and compiling the multiaspect projection data space. Sample tomographic sonar images of a practice sea mine, a Mk 84 bomb, and the sea floor itself, are presented.

Contributed Papers

1:50

1pSP2. Fin and humpback whale vocalization classification and localization, northern Georges Bank. Wei Huang (Elec. and Comput. Eng., Northeastern Univ., 500 Broadway, Apt. 3157, Malden, MA 02148, huang.wei@husky.neu.edu), Delin Wang, and Purnima Ratilal (Elec. and Comput. Eng., Northeastern Univ., Boston, MA)

Several tens of thousand vocalizations from multiple fin whale individuals were passively recorded by a high-resolution coherent hydrophone array system in the Gulf of Maine in Fall 2006. The recorded fin vocalizations have short durations roughly 0.4 s and frequencies ranging from 15 to 40 Hz. The fin vocalizations were detected via spectrogram intensity thresholding. The horizontal azimuth or bearing of each detected fin whale vocalization was determined by broadband beamforming. Each vocalization was then characterized using numerous features, such as center frequency, upper and lower frequency limits, and duration, obtained from pitch tracking. These vocalizations were then classified using Bayesian-based Gaussian Mixture model feature clustering into several distinct vocal types. The vocalization clustering result was then combined with the bearing-time trajectory and localized by the moving array triangulation and the array invariant techniques. The vocalization types are found be dependent on the geographic region, suggesting a potential application for monitoring different fin whale groups from their vocalization features. A similar approach can be used to monitor humpback whale groups.

2:05

1pSP3. Micro-aperture bio-inspired broadband sonar model and system for underwater imaging applications. Jason E. Gaudette (Sonar and Sensor Systems, NUWC Div. Newport, 1176 Howell St., B1320/135, Newport, RI 02841, jason.e.gaudette@navy.mil), Philip Caspers (Mech. Eng., Virginia Tech, Blacksburg, VA), and James A. Simmons (Dept. of Neurosci., Brown Univ., Providence, RI)

Conventional angular sonar imaging is based principally on the correlation of signals received across individual elements in an array. Thus, array signal processing simply matches a particular set of time delays (or equivalently, phase shifts) to the corresponding arrival angles. The angular resolution of such conventional systems is fundamentally limited by the aperture-to-wavelength ratio. The biosonar of echolocating bats and dolphins provide inspiration that we can significantly overcome these aperture-to-wavelength limits by two orders of magnitude. The key to success lies in the use of multiple octaves of bandwidth. Previous work in bat echolocation has shown how multiple overlapping echoes in range can be deconvolved through spectral pattern matching of broadband interference notches. Recent modeling and simulation results show how these bio-inspired broadband interferometric techniques can be extended to the angular imaging problem despite having only two elements spaced at 1 to 4 λ. Acoustic tank testing results from an underwater prototype array will also be presented. [Work supported by ONR 341 and internal investments by NUWC Division Newport.]

Invited Papers

2:20

1pSP4. Hostile fire detection using a bio-inspired mobile acoustic sensor network. George Cakiades (US Army ARDEC, 407 Buffington Rd., Picatinny Arsenal, NJ 07806, george.cakiades.civ@mail.mil), Socrates Deligeorges (BioMimetic Systems, Cambridge, MA), Jemin George (Army Res. Lab, Adelphi, MD), Felipe Núñez (Univ. of California, Santa Barbara, Santa Barbara, CA), Yongqiang Wang (Clemson Univ., Clemson, SC), and Francis J. Doyle (Harvard Univ., Cambridge, MA)

Hostile Fire Detection (HFD) sensors play an increasing role in combating asymmetric threats in both military and civilian operations. Bio-inspired advances in acoustic sensor technology have enabled small aperture arrays to localize and identify target sounds on baselines as small as 7.5 cm, making them practical for body worn and mobile applications such as UAVs. The unique approach to acoustic processing reduces acoustic information through a neural transform to key features that allow segregation of multiple targets using spectro-temporal cues creating auditory objects. The sparse representation of targets as auditory objects enables fast computationally efficient localization, identification, and tracking of several acoustic targets nearly simultaneously. The sparse representation is also ideal for information fusion among sensors over limited bandwidth networks for enhanced performance in challenging environments. Through a collaborative effort between Army research groups, the University of California Santa Barbara, and BioMimetic Systems, a prototype acoustic sensor network using biologically inspired sensors and network synchronization for a mobile HFD application has been developed. The network employs body worn PinPoint™ HFD sensors interfaced with smartphones (Android) running net-centric fusion algorithms. The network will be discussed in terms of the biologically inspired components, information fusion, as well as results from preliminary field tests.

2:40

1pSP5. Green's function retrieval for atmospheric acoustic propagation. Sandra L. Collier, Jericho E. Cain, John M. Noble, W. C. K. Alberts, David A. Ligon, and Leng K. Sim (U.S. Army Res. Lab., 2800 Powder Mill Rd., RDRL-CIE-S, Adelphi, MD 20783-1197, sandra.l.collier4.civ@mail.mil)

There is an extensive classical utilization of the Green's function for wave propagation in many different media. By extracting the Green's function, or medium impulse response, one may obtain information about the medium channel. This information could be used to overcome the medium effects, as is done in time-reversed acoustic localization or acoustic communications; alternatively, it may be used to deduce information about the medium. The use of time-reversal methods has been established for interferometry, phase conjugation, and time-reversal mirrors and cavities. The objective of this research is to determine the feasibility of using a time-reversal method to extract a Green's function for outdoor acoustic propagation utilizing sources in the audible frequency ranges. Initial findings are presented here.

3:00–3:15 Break

Contributed Papers

3:15

1pSP6. Matched-field source localization with multiple small-aperture arrays. Dag Tollefsen (Norwegian Defence Res. Establishment (FFI), Boks 115, Horten 3191, Norway, dag.tollefsen@ffi.no) and Stan E. Dosso (School of Earth and Ocean Sci., Univ. of Victoria, Victoria, BC, Canada)

This paper considers combining information from multiple small-aperture arrays in matched-field processing (MFP) for source localization. Assuming individual arrays are comprised of calibrated sensors which are synchronized in time, conventional MFP can be applied for each array and the resulting Bartlett processors summed over arrays. However, if the relative calibration and/or time synchronization is known between some or all arrays, more informative multiple-array processors can be derived by maximum-likelihood methods. For example, if the relative calibration between arrays is known, the observed amplitude variations between arrays provide additional information for source localization; if synchronization is known, phase variations provide localization information. Various multiple-array processors are derived and evaluated in terms of the probability of correct localization from Monte-Carlo analyses for a range of signal-to-noise ratios and number of frequencies for simulated shallow-water scenarios with vertical and horizontal arrays. Effects of environmental mismatch in seabed geoacoustic parameters and water depth are also considered. The analysis indicates that, dependent on array configurations, substantial improvements in source localization performance can be achieved when including relative amplitude and/or phase information in the multiple-array processor. The improvement is reduced by environmental mismatch; this degradation can be partially mitigated by including additional frequencies in the processing.

3:30

1pSP7. Acoustic tracking of small aircraft within an airport. Alexander Sedunov, Alexander Sutin, Nikolay Sedunov, Hady Salloum, Alexander Yakubovskiy (Stevens Inst. of Technol., 711 Hudson St., Hoboken, NJ 07030, asedunov@stevens.edu), and David Masters (Sci. and Technol. Directorate, Dept. of Homeland Security, Washington, DC)

The Acoustic Aircraft Detection (AAD) system developed by Stevens Institute of Technology for the detection of small aircraft in remote border areas was tested for tracking small aircraft in the airport. The goal of the test was to demonstrate a proof-of-concept capability for the acoustic sensor when applied to tracking aircraft during take off, landing, or taxing in a small airport. Two AAD nodes with five microphones were used to find the direction of arrival of sound produced by an aircraft using time-difference of arrival to pairs of sensors and to localize those by triangulation in real time. Additionally, a portable acoustic recorder system (PARS) with three microphones arranged in a ground plane was deployed to provide more data for post-processing analysis. The nodes separation varied between 150 and 250 m in different experiments. During the two-day experiment, aircraft activity of regular airport traffic was observed. At least 14 different aircraft were recorded during various movement on airport runways as well as takeoff and landing. The tested AAD was developed for another mission and was far from an optimal acoustic system for small airport applications. Suggestions for this system will be presented. [This work was sponsored by DHS S&T.]

3:45

1pSP8. Nearfield acoustic holography in noisy environment based on the measurement using an acoustic mask with microphone array. Shang Xiang and Weikang Jiang (Shanghai Jiao Tong Univ., 800 Dong Chuan Rd., Shanghai 200240, China, wkjiang@sjtu.edu.cn)

Nearfield acoustic holography (NAH) has been widely used for identifying acoustic noise sources. However, conventional NAH is theoretically available only in the free field; therefore, the NAH may meet difficulties in many application *in-situ* environments. An NAH based on the measurement using an acoustic mask with microphone array is proposed in this presentation to reconstruct sound pressure and velocity of target sources in the environment with reflections and disturbing acoustic noise sources. The microphone array is flush-mounted at the bottom plane of an open rectangular mask. Four side surfaces are designed to acquire sound pressure in Neumann's boundary condition. In an actual measurement, the mask faces to near field of a target source. Although the sound wave from disturbing sources may propagate into the mask by passing through the gap between the mask and source surface, the disturbing waves can be decomposed by the proposed NAH using inverse patch transfer functions. Numerical simulations and experiments indicate that this novel NAH using mask with microphone array is valid for reconstructing sound source in noisy environment. The influence of different distances between the source surface and the mask is also investigated.

4:00

1pSP9. Detection results for a class 1 unmanned aerial vehicle measured with a small microphone array. Geoffrey H. Goldman (U.S. Army Res. Lab., 2800 Powder Mill Rd., Adelphi, MD 20783-1197, geoffrey.h.goldman.civ@mail.mil)

The Department of Defense is developing low size, weight, power, and cost (SWaP-C) acoustic systems to detect and track small unmanned aerial vehicles (UAV). To support these goals, an analysis of several detection algorithms was performed using acoustic data generated with a class I unmanned aerial vehicle and measured with a small tetrahedral microphone array. The detection algorithms were based upon the peak output power and the coherence factor of several beamforming algorithms. Receiver operation characteristics (ROC) curves were generated using both an energy-based and a Neyman-Pearson-based detection algorithm.

4:15

1pSP10. Atmospheric compensation of acoustic signatures of aircraft. Minas Benyamin and Geoffrey H. Goldman (U.S. Army Res. Lab., 2800 Powder Mill Rd., Adelphi, MD 20783-1197, geoffrey.h.goldman.civ@mail.mil)

The U.S. Army Research Laboratory is investigating using low size, weight, power, and cost (SWaP-C) acoustic sensors to classify unmanned aircraft systems (UAS). One issue complicating UAS classification using acoustics is that the atmosphere attenuates the signature of the targets in a complex manner. To address this issue, we developed and tested a technique to mitigate the effect of atmospheric attenuation. We used Bass's model with inputs from temperature, relative humidity and range to estimate atmospheric attenuation, then we used techniques based upon a Wiener filter implemented in the frequency domain to adjust the amplitude of the measured signal. The Wiener filter reduced the amplification of the noise while improving the reproducibility of the signature at different ranges, particularly at higher frequencies. The results suggest that preprocessing the data using this technique should improve the performance of acoustic classifier algorithms.

MONDAY EVENING, 2 NOVEMBER 2015 GRAND BALLROOM FOYER, 5:30 P.M. TO 7:00 P.M.

Exhibit and Exhibit Opening Reception

The instrument and equipment exhibit is located near the registration area in the Grand Ballroom Foyer.

The Exhibit will include computer-based instrumentation, scientific books, sound level meters, sound intensity systems, signal processing systems, devices for noise control and acoustical materials, active noise control systems and other exhibits on acoustics.

The Exhibit will open on Monday with an evening reception with lite snacks and a complimentary drink.

Exhibit hours are Monday, 2 November, 5:30 p.m. to 7:00 p.m., Tuesday, 3 November, 9:00 a.m. to 5:00 p.m., and Wednesday, 4 November, 9:00 a.m. to 12:00 noon.

Coffee breaks on Tuesday and Wednesday mornings (9:45 a.m. to 10:30 a.m.) will be held in the exhibit area as well as an afternoon break on Tuesday (2:45 p.m. to 3:30 p.m.).

The following companies have registered to participate in the exhibit at the time of this publication:

Brüel & Kjær Sound & Vibration Measurement—www.bksv.com

Freudenberg Performance Materials—www.Freudenberg-pm.com

G.R.A.S Sound & Vibration—www.gras.us

PCB Piezotronics—www.pcb.com/

Sensidyne—www.sensidyne.com

Springer—www.Springer.com

Teledyne Reson—www.teledyne-reson.com

Payment of an additional fee is required to attend.

MONDAY AFTERNOON, 2 NOVEMBER 2015 GRAND BALLROOM 6, 7:00 P.M. TO 9:00 P.M.

1eID

Interdisciplinary: Tutorial Lecture on Sonic Booms: A "Super" Sonic Saga

James P. Cottingham, Chair
Physics, Coe College, 1220 First Avenue, Cedar Rapids, IA 52402

Chair's Introduction—7:00

Invited Paper

7:05

1eID1. Interdisciplinary tutorial on sonic booms: A "super" sonic saga. Victor W. Sparrow (Grad. Program in Acoust., Penn State, 201 Appl. Sci. Bldg., University Park, PA 16802, vws1@psu.edu)

This tutorial will provide an introduction to sonic booms, including background, current status of research, and future prospects. Supersonic aircraft generate sonic booms, so the physics of shock propagation through the atmosphere is involved. But those shocks are ultimately heard on the ground indoors and outdoors, both by people and wildlife. Hence, physical acoustics, psychological and physiological acoustics, animal bioacoustics, structural acoustics, vibration, and noise are all involved. Aircraft manufacturers have plans to build new civilian supersonic passenger aircraft, and these new aircraft intend to have sonic booms that are much quieter than those produced by either military aircraft or the now-retired Concorde supersonic airliner. Thus, an additional objective of this tutorial is to provide a quick-start technical basis for ASA members to understand the basics of sonic booms, enabling them to communicate effectively about sonic booms. If the aircraft manufacturers meet their stated goals, millions of people around the world will potentially begin hearing quiet sonic booms in the future. The material is highly interdisciplinary and should be useful both to the curious and to specialists across almost all of the Acoustical Society of America's technical areas. [The opinions, findings, conclusions, and recommendations stated here are those of the author and do not necessarily reflect the views of sponsors of the ASCENT Center of Excellence including the Federal Aviation Administration.]

In conjunction with the Tutorial Lecture on sonic booms on Monday evening, Gulfstream Aerospace Corporation will be bringing their sonic boom simulator to the Jacksonville, FL meeting. The Supersonic Acoustic Signature Simulator II is a specially equipped mobile audio booth designed to accurately reproduce the noise an observer on the ground would hear if a supersonic aircraft flew by. More specifically, the visitor at the ASA meeting will experience a back-to-back comparison of two radically different synthesized sonic booms. The first sonic boom signature will represent the "traditional" N-wave signature produced by the Concorde. The second sonic boom will represent a shaped signature that is representative of a low-boom aircraft. The intent of this demonstration is to provide the visitor with an opportunity to experience a fully immersive simulation that contains a sophisticated auralization of stimuli that contribute to subjective response caused by a sonic boom.

The simulator will only be available on Monday, November 2 (12:00 noon to 7:00 p.m.), and Tuesday, November 3 (9:00 a.m. to 6:00 p.m.), and will be located at Jacksonville Landing, just steps away from the Hyatt Regency. Walking directions will be provided on site via convenient signs. Please come and take advantage of this special opportunity to hear the Supersonic Acoustic Signature Simulator II.