Session 5aAB

Animal Bioacoustics: New Discoveries in Bat Vocal Communication

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Chair's Introduction—8:20

Invited Papers

8:25

5aAB1. Signature calls predict foraging success in big brown bats (*Eptesicus fuscus*). Genevieve S. Wright (Dept. of Biology, Univ. of Maryland, College Park, MD 20742, myotis@gmail.com), Chen Chiu, Wei Xian (Dept. of Psychol. and Brain Sci., Johns Hopkins Univ., Baltimore, MD), Gerald S. Wilkinson (Dept. of Biology, Univ. of Maryland, College Park, MD), and Cynthia F. Moss (Dept. of Psychol. and Brain Sci., Johns Hopkins Univ., Baltimore, MD)

Animals foraging in the dark must simultaneously pursue prey, avoid collisions, and interact with conspecifics, making efficient non-visual communication essential. A variety of birds and mammals emit food-associated calls that inform, attract, or repel conspecifics. While echolocation by the insectivorous, aerial-hawking big brown bat *(Eptesicus fuscus)* has been studied extensively, communicative calls used by this species have received comparatively little research attention. We report on a rich repertoire of vocalizations produced by big brown bats in a large flight room equipped with synchronized high-speed stereo video and audio recording equipment. We also provide evidence that a specific social call, the "frequency-modulated bout" (FMB), which is emitted only by males, exclusively in a foraging context, and only when conspecifics are present, predicts the caller's foraging success and is individually distinct. Bats were studied individually and in pairs, while sex and experience with a foraging task were experimentally manipulated. Individuals emitting a higher number of FMBs showed greater prey capture success. Following FMB emission, inter-bat distance, diverging flight, and the other bat's distance to the prey increased. These findings highlight the importance of vocal communication for nocturnal animals mediating interactions in a fast-paced foraging setting.

8:45

5aAB2. Ultrasonic and superfast: Design constraints on echolocation in bats. John Ratcliffe (Dept. of Biology, Univ. of Toronto Mississauga, 3359 Mississauga Rd., Mississauga, ON L5L 1C6, Canada, j.ratcliffe@utoronto.ca)

Recent work from our group demonstrates that two exceptional characteristics of bat biosonar—bats' extremely high call emission rates and these calls' ultrasonic frequencies—reflect biomechanical constraints of the vocal apparatus. We hypothesized that smaller bats, with their smaller mouths, emit higher frequencies to achieve sufficiently directional sonar beams, and that variable directionality is critical for bats. We found that six aerial hawking, vespertilionid bat species produced sonar beams of similar shape and volume, and we predict that many bats adjust their acoustic field of view to suit habitat and task. We speculate that sonar beam shape has been an evolutionary constraint on echolocation and explains the bat size-call frequency correlation. During the terminal phase of an aerial hawking attack on an insect, bats produce a "buzz," increasing information update rates by producing >160 calls/second. We discovered that bats use specialized superfast muscles to power these rapid call rates. We also show that laryngeal motor performance, not call-echo overlap, limits maximum call rate. We suggest that the advantages of rapid auditory updates on prey movement have selected for superfast laryngeal muscle. Taken together, our results provide further evidence that bat biosonar is a dynamic sensory system, a sensory system that allows bats to adjust and optimize their acoustic fields of view and to update their auditory scene at rates >160 times/second to optimize airborne prey detection and tracking.

9:05

5aAB3. Probabilistic strategies for dynamic coordination of biosonar emissions in social groups. Michael Smotherman (Biology, Texas A&M Univ., 3258 TAMU, College Station, TX 77843-3258, smotherman@tamu.edu)

Echolocating bats are social animals and must be able to use their biosonar capabilities in a wide range of social contexts. Bats roosting or flying in groups routinely adapt their pulse emissions to accommodate sharing the acoustic space with potentially many bats. In this regard, echolocation may be bound by the same rules and constraints governing social communication. Bats can alter pulse acoustics, temporal patterns, projections patterns, and locomotor trajectories to minimize acoustic interference across individuals. Here, we present evidence that the highly gregarious free-tailed bat, *Tadarida brasiliensis*, primarily relies upon probabilistic strategies for mitigating acoustic interference rather than trying to predict or extract information from the pulses of other bats. When free-tailed bats hear

the pulses of another bat they shift the timing of subsequent pulse emissions following a randomized back-off algorithm similar to those that have evolved in artificial wireless communications systems. Importantly, this behavior is only effective if all bats strictly follow the same strategy. I will present the results of recent measurements of this back-off algorithm and use computational modeling to illustrate how and when it improves sonar imaging in social settings.

9:25

5aAB4. Vocal flexibility and regional variation in free-tailed bat songs. Israel Salazar (Biological Sci., Florida Int.. Univ., 11200 S. W. 8th St., Office DM 438A, Miami, FL 33199, isala004@fiu.edu) and Kirsten Bohn (Biology, Johns Hopkins Univ., Baltimore, MD)

Male Brazilian free tailed bats (*Tadarida brasiliensis*), sing to attract females and defend territories during the mating season. These songs are unusual among mammalian vocalizations in that they are highly complex and hierarchically structured. Songs are composed of multiple syllables which are combined into three phrases that vary in number and order across renditions. While much work has been done on regional vocal variation in birds, relatively a few studies have found similar evidence in mammals. This study aimed to determine if *T. brasiliensis* songs vary across agographical regions. To accomplish this, we compared spectro-temporal characteristics, and phrase composition of songs recorded from wild colonies in various locations throughout Florida, Georgia, and Texas. Although we found considerable inter-individual and within-individual variation, there are salient regional differences in song structure. These findings combined with a high level of within-individual flexibility, and the lack of local adaptation in foraging echolocation pulses, support a possible role of vocal learning in song production in this species.

9:45–10:00 Break

10:00

5aAB5. Geographic variation in contact calls emitted by a leaf-roosting bat suggest distinct modes of vocal transmission. Karina Montero and Erin H. Gillam (Biological Sci., North Dakota State Univ., NDSU Dept. 2715, Stevens Hall 201, PO Box 6050, Fargo, ND 58108-6050, Erin.Gillam@ndsu.edu)

Group behaviors, such as coordination and information exchange, are typically mediated by acoustic signals known as contact calls. Although these vocalizations are widespread, the mechanisms driving variation in acoustic features within and between populations remain poorly understood. Our study examines whether patterns of variation in two contact calls emitted by Spix's disk winged bats, *Thyoptera tricolor,* are congruent with patterns of genetic distance among populations isolated by a geographic barrier. *T. tricolor* is a leaf roosting bat that forms stable social groups and exhibits all-offspring philopatry. To evaluate if vocal variation between groups is influenced by genetic distance, we studied the variation in microsatellite allele frequencies at multiple sites on the Caribbean and Pacific mountain slopes. We found that the geographic variation patterns differed between the two types of calls studied, and we argue that this indicates distinct modes of vocal transmission. Our results suggest that one contact call is likely socially transmitted via vocal learning, while the congruence between patterns of genetic differentiation and acoustic variation for the second call type suggest this is an inherited trait. Further research is needed to better understand the role of vocal learning and genetic transmission of contact calls emitted by *T. tricolor*.

10:20

5aAB6. Singing away from home: Song is used to create and defend foraging territories in the African megadermatid bat, *Cardioderma cor*. Grace C. Smarsh (Biology Dept., Texas A&M Univ., 3258 TAMU, College Station, TX 77843-3258, gsmarsh@bio.tamu.edu)

The diversity of song repertoires and functions of singing in mammals are not well known. In bats, singing in the roost to court and defend mates has been studied; however, the concept of territorial behaviors and the role of singing outside of the roost is poorly understood. The heart-nosed bat, *Cardioderma cor*, roosts in mixed-sex and age groups in the hollows of baobab trees, but disperses to exclusive areas whereupon they move about foraging and singing. We investigated singing in this species by mist-netting, pit-tagging, and tracking 12 singing individuals during which we recorded songs and collected singing and movement behavioral data. We conducted song playbacks to further test song function. Male *C. cor* individuals return to same foraging area nightly, which are often over 100 m across, and favor perches where they sing back and forth with neighbors. Low-frequency, repetitive syllables are likely adapted for song transmission across the cluttered bush habitat. Songs vary within and across individuals both spectrally and temporally. Song playbacks elicited aggressive responses, confirming that these bats use song as part of their territorial defense strategy, similar to the way song is used by many songbirds.

10:40

5aAB7. Describing the social behavior of the Indiana bat at day roost sites. Caroline M. Byrne (Biology, Indiana State Univ., 276 Canco Rd., Portland, ME 04103, caroline.byrne@briloon.org) and Joy M. O'Keefe (Biology, Indiana State Univ., Terre Haute, IN)

Bats are highly social, but the study of bat social behavior was limited until recently due to technological limitations. Most of bat behavior is imperceptible to our senses, including both their use of ultrasound and their nocturnal activities. During the maternity seasons (May–August) of 2013 and 2014 near Plainfield, Indiana, we recorded Indiana bat (*Myotis sodalis*) roost site behaviors with passive emergence count observation, video (Sony Nightshot HandyCams and IR lights), and acoustics (Pettersson D500X acoustic detectors). The objective of this study was to compile a catalog of visual and acoustic behaviors seen at Indiana bat day roost sites. Thus far, we have detected 29 specific types of visual behavior, and five general types of acoustic behavior. The documented behaviors include visual behaviors similar to those categorized as "checking behavior" and acoustic behaviors seen in contexts of agonistic, echolocation, infant isolation, and disturbance in little brown bats (*Myotis lucifugus*). These are some of the first systematic observations of social behavior for Indiana bats. Understanding the social behaviors of these highly social bats is crucial to gaining a full understanding of their life cycle and daily requirements.

11:00

5aAB8. Territorial calls analysis in the broad tailed bat (*Nyctinomops laticaudatus*). Fernando J. Montiel Reyes (Bioconservación y manejo, Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, 60 Brezo St., Colonia Nueva Santa María, Mexico City, Azcapotzalco 02800, Mexico, fercho_mom@hotmail.com), Kirsten Bohn (Johns Hopkins Univ., Baltimore, MD), and Jorge Ortega (Bioconservación y manejo, Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, Mexico City, Mexico)

Some bat families perform vocalizations called "songs" to mate, conformed by three element types: chirps, trills, and buzzes. Also, those might be territorial warning calls; but its syntax remains to be understood. Our goal is to get information about mating calls' patterns and its clarified function for a molossid bat species. We used ultrasound microphones to record vocalizations from a colony of *Nyctinomops laticaudatus*, during three periods through 2013–2014. We performed spectrogram analysis to characterize vocalizations with chirp number, duration, and acoustic frequency measurements. Results show males perform structured and complex songs. Vocal repertoire features two chirp types, trills, and buzzes as in other species. Chirp A is a short descendant frequency modulated pulse of 8.05 ms (SD = 3.53 ms); chirp B is a downward FM larger than A with an upward final segment of 43.93 ms total length (SD = 14.85 ms). Distinctively *Nyctinomops laticaudatus* performs songs of a series of three to nine compound chirps, starting with B element of high plasticity. Additionally structure is modified by the syntax, with shorter phrases when the first element is a trill or a buzz.

11:20

5aAB9. Bats as new models for social communication. Kirsten M. Bohn (Johns Hopkins Univ., Dunning Hall, Ste. 434, Baltimore, MD 21218, kbohn1@jhu.edu)

Bat echolocation has been the focus of extensive acoustic research for over 50 years. However, our knowledge of bat social communication is in its infancy, having really only begun to develop over the last decade. This is because only recently have ultrasonic recording and playback become affordable, rugged, and portable—making field research highly expedient. These advances have in essence opened up an entirely new frontier in acoustic research. Indeed a very large frontier with over 1000 diverse species, nearly all of which are highly social. Here, I review the types of vocalizations bats produce, from echolocation calls, to simple calls to complex songs. For example, simple infant isolation calls are produced by the majority of mammals with little to no specialization in bats. In contrast, our work on Molossid bats shows that they embed "echolocation" calls into complex song phrases while roosting and in flight. In this case, social communication is likely an exaptation of the highly specialized echolocation system. Finally, I discuss where bats fit into our current models—birds, anurans, cetaceans, and rodents—and how using a comparative approach can greatly expand our understanding of acoustic communication.

11:40–12:00 Panel Discussion

FRIDAY MORNING, 6 NOVEMBER 2015 CITY TERRACE 7, 9:00 A.M. TO 10:30 A.M.

Session 5aAO

Acoustical Oceanography and Underwater Acoustics: Topics in Acoustical Oceanography

Gopu R. Potty, Chair
Ocean Engineering, University of Rhode Island, Narragansett Bay Campus, Narragansett, RI 02882

Contributed Papers

9:00

5aAO1. Analytical discussion of past measurements of acoustic attenuation in mud sediments and of possible future experimental approaches. Allan D. Pierce (PO Box 339, 399 Quaker Meeting House Rd., East Sandwich, MA 02537, allanpierce@verizon.net), William L. Siegmann, and Elisabeth Brown (Mathematical Sci., Rensselaer Polytechnic Inst., Troy, NY)

Attenuation of compressional waves in mud is higher than in sea water, and less than in sandy/silty sediments. For experiments reported in 1964 (Acustica) by Wood and Weston, the Inferred circumstances are a 1 m thick mud slab overlying a gravel bottom, with air above (low tide), and with source and receiver either at the mud-gravel interface or slightly above it. Frequencies from 4 kHz to 72 kHz were transmitted, with signals received at a succession of horizontal distances of up to 50 m. Reported data in decibels versus range show considerable erratic behavior. Attempt is made to explain this behavior using a full-wave analysis of a Pekeris waveguide, with a fluid layer (the mud slab) overlying a (fluid or elastic) half-space, with a series of plausible guesses concerning the properties of the half-space. The conclusion is that the data and the circumstances allowed considerable variability in the attenuation estimates, but those made by Wood and Weston were about as good as could be expected. it is argued that placing source and receiver near the interface was a relatively poor choice, and that future experiments of this general type might give better results with the use of vertical arrays.

9:15

5aAO2. Experimental design for sediment characterization in the New England Mud Patch. Gopu R. Potty, James H. Miller (Dept. of Ocean Eng., Univ. of Rhode Island, 115 Middleton Bldg., Narragansett, RI 02882, potty@egr.uri.edu), and James F. Lynch (Appl. Ocean Phys. & Eng., Woods Hole Oceanographic Inst., Wood Hole, MA)

This study focuses on the design of an experiment to estimate the shear wave properties of ocean bottom sediments at a location in the southern

New England Continental Shelf called the "New England Mud Patch." The mud patch is a 13,000 square kilometer area covered by fine-grained sediment. The inversion technique is based on collecting interface wave (Scholte wave) data using geophones on the sea bottom. The data for the inversion consist of Scholte wave phase velocity dispersion calculated from the geophone array data. The present study aims at applying this Scholte wave based shear wave inversion technique to the "mud patch" area. Two different interface wave measurement systems will be presented. Appropriate source to receiver ranges will be explored based on simulations. The engineering challenges associated with deploying the system in a soft seabed will be investigated and design modifications will be investigated. Acoustic and sediment data from the 1996 Shelf Break Primer experiment, which was conducted in the western side of the mud patch, will be reviewed. The simulations will be based on historic sediment and acoustic data. [Work sponsored by Office of Naval Research, code 322 OA.]

9:30

5aAO3. Comparisons between a spherical aggregation of scatterers, and hard and soft spheres using single-frequency and pulsed signals. Adaleena Mookerjee and David R. Dowling (Mech. Eng., Univ. of Michigan, 1231 Beal Ave., 2010 Autolab, Ann Arbor, MI 48109, adaleena@umich.edu)

When sound is projected into the ocean, the backscattered signal may provide information about the object(s) from which the sound has scattered. When the backscattered sound comes from an aggregation of strong scatterers, such as a school of fish at their swim-bladder resonance frequency, a phenomenon called Coherent Backscatter Enhancement (CBE) may occur, and this phenomenon could aid in discriminating fish schools from other similar-strength scatterers in the ocean water column. When CBE occurs, the addition of in-phase scattered waves from propagation path pairs produces a scattered field intensity enhancement of as much as two in the direction opposite to that of the incident wave. This presentation describes the results of CBE simulations of spherical aggregations of scatterers based on the Foldy (1945) equations, and provides comparisons to backscattering from single perfectly reflecting spheres. Interestingly, a spherical aggregation of 4200 strong scatterers with wave number scaled radius $ka = 32$ may provide backscattering equivalent to that from a single larger perfectly-reflecting sphere with $ka = 53$. Additional simulation comparisons involving the statistics and time histories of harmonic and frequency sweep incident waves are shown. [Work supported by the Office of Naval Research and by Advanced Research Computing at the University of Michigan.]

9:45

5aAO4. Compressive ocean acoustic sound speed profile estimation in shallow water. Michael Bianco and Peter Gerstoft (Marine Physical Lab., Scripps Inst. of Oceanogr., Univ. of California San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0238, mbianco@ucsd.edu)

The estimation of ocean acoustic sound speed profiles (SSPs) requires the inversion of an acoustic transmission model using limited observations. Provided the parameters of the inverse model are sparse, Compressive Sensing (CS) can help solve such underdetermined problems accurately, efficiently, and with enhanced resolution. Here, CS is used to estimate range-independent acoustic SSPs in shallow water ocean environments using a normal-mode representation of the acoustic field. Two sparse parameterizations of the SSPs are considered. The first parameterization assumes that change in the sound speed with depth is sparse and that the SSP can be constructed from a limited number of dominant changes in sound speed. The second case assumes *a priori* information about the ocean SSP variability in terms of Empirical Orthogonal Functions (EOFs), estimating the dominant EOFs describing the current SSP. For both cases, both real and synthetic acoustic data are processed. It is shown that in the CS framework, both of the optimizations can be solved with increased resolution and robustness over traditional methods.

10:00

5aAO5. Using broadband acoustic signals and modal behavior to assess scales of ocean variability in shallow water waveguides. Mohsen Badiey (College of Earth, Ocean and Environment, The University of Delaware, 107 Robinson Hall, Newark, DE 19716, badiey@udel.edu) and Marshall H. Orr (College of Earth, Ocean and Environment, The University of Delaware, Bryantown, MD)

The sound speed fields of the continental shelf water column are anisotropic and have "fronts" related to propagating internal wave packets. The angle between a broadband acoustic signal's source–receiver propagation track and the propagating "fronts" affects its modal composition. If the temporal variability of the modal behavior of the acoustic signals are monitored in time and space, one might identify the fluid process that causes the changes to the sound speed field. In this paper, we first present a heuristic view of how the modal properties of broadband signals can be affected by the sound speed field variability caused by propagating internal wave packets. We then present three days of acoustic field data acquired on vertical and horizontal arrays placed in ~100 m of water about 20 km from the location of acoustic signal sources. Temporal changes in the received acoustic signal's modal composition will be compared to numerical simulations. The changes in modal composition will be correlated to internal wave induced variability in the horizontal refraction of the signals.

10:15

5aAO6. Measurements and modeling of the variability in normally incident reflections from the seabed. Saroj Bardewa and Martin Siderius (Dept. of Elec. and Comput. Eng., Portland State Univ., Portland, OR 97201, saroj@pdx.edu)

Normal incidence reflection measurements taken during the TREX13 experiment off the coast of Florida show substantial variability. One likely source of variability is due to scattering from the rough surface of the seabed. These data were taken from an omnidirectional source at a relatively low frequency (around 3 kHz). Systems being considered for measuring seabed properties (such as sound speed, density, and roughness) may use commercial echo-sounders that are directional and operate at much higher frequencies. Measurements from the TREX13 data as well as higher frequency systems are analyzed together with modeling to determine how surface roughness effects these measurements. The modeling uses an integral equation approach with a power law roughness spectrum to calculate backscattering of incident plane waves. The effects of changing the model parameters such as seabed type and roughness on the nature of backscattering are examined. The simulated results are compared with the measurements obtained from the experiments. The measurements are further used to calculate the statistical parameters to understand the nature of the normal reflection from a rough seabed.

Session 5aMU

Musical Acoustics: General Topics in Musical Acoustics

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

Contributed Papers

8:30

5aMU1. The inner ear as a musical instrument. Brian Connolly (Music Dept., Maynooth Univ., Logic House, Maynooth Co. Kildare, Ireland, bconnolly1987@gmail.com)

This paper addresses the place of the ears and their potential as musical instruments. Psychoacoustics research into the non-linearities of the inner ear has proven that the organ has much more to offer the composer than has been previously considered. By reversing the role of the ear from being a submissive receiver to an active participant in the creative process, an exciting level of opportunity opens up for the composer. A focus is given in this paper to bandwidth phenomena and auditory distortion products with references to the author's own compositional material which seeks to highlight that the investigation of the non-linear nature of the inner ear is revolutionary in relation to the place of the ear within contemporary composition. Central to this work is the notion that the ear is not simply a passive component of the musical experience. Adorno once stated that the ear is a "dozy and inert" organ and by disproving such a view one can destabilize common assumptions about psychoacoustics and the potential of the ears as musical instruments.

8:45

5aMU2. Input impedance of sheng pipes augmented with resonators. Matthew F. LeDuc (Phys. Dept., Univ. of Michigan, Ann Arbor, MI 48109, mafrledu@umich.edu), Nathan K. Haerr, Chevelle N. Boomershine, and James P. Cottingham (Phys., Coe College, Cedar Rapids, IA)

The sheng is a free reed mouth organ constructed of bamboo pipes with a free reed in each pipe near one end. A version commonly available today has 17 pipes in a circular arrangement with the reeds enclosed in a wind chamber. The pipes are nearly cylindrical over a significant portion of their length, but the bore near the reed end becomes approximately conical. A traditional instrument of China, the sheng, has a long recorded history, but a number of enlarged and modernized versions were created in the twentieth century, some featuring keys and additional pipes. The sheng in the current study is a standard 17-pipe configuration, with cylindrical metal pipe resonators attached to most of the pipes. These resonators amplify the radiated sound and also alter the tone quality. Calculations of input impedance have been made for the pipes, with and without the resonators attached, taking into account the position of the reed along the pipe, tuning slots, finger holes, and non-circular pipe cross sections. These calculations are compared with the measured pipe impedances as well as the measured sounding frequencies and sound spectra. [Research supported by NSF REU grant PHY-1004860.]

9:00

5aMU3. Empirical study of violin acoustics and its perception under various mutes. Sina Mousavion (SciTec, Ernst Abbe Fachhochschule-Jena, Jakobsplan 1, Nr. 02-09-07-0, Weimar 99423, Germany, sina.mousavion@yahoo.com) and Suchetana Sarkar (SciTec, Ernst Abbe Fachhochschule-Jena, Heidelberg, Germany)

Violinists often practice with mutes, the purpose of which is to reduce the volume so the sound does not disturb other people. There is however a great disadvantage; practice mutes not only lower the volume but change the timbre dramatically, making it unpleasant to the ear. Previous researches mostly focus on how to find the elusive "Stradivarius Sound." On the other hand, via sound analysis, we empirically study different mutes, in order to identify the markers that allow the violin to retain its "Signature Sound." The general problem lies in the complexity of violin sound propagation and its perception. Here, we show that all types of mutes necessarily diminish the frequency band of 1.5–2.5 kHz, which tips the balance of the sound toward a darker color. The results demonstrate that unless a proportional balance between the amplitude of the harmonics of each tone is maintained, the sound loses its Brilliance character. In addition, some mutes tend to add spurious resonance peaks at lower frequencies, which further emphasizes the imbalance of tones in the lower regions. These factors can aid in the development of a mute that does not inhibit the intrinsic characteristic of the violin.

9:15

5aMU4. Acoustic and structural resonance characteristics of the cajon. John Pehmoeller and Daniel Ludwigsen (Kettering Univ., 1700 University Ave., Flint, MI 48504, pehm3247@kettering.edu)

The cajon is a percussion instrument with origins in 16th century Peru. Literally translated "crate," the cajon was originally a crate that players sat upon and struck to make rhythmic patterns. The modern version is a wooden box, closed except for a hole in the back panel. The front panel is struck with the hands or one of several types of beaters. The front panel is thinner than the others and is often attached with a slightly loose top edge for a snare-like effect. Alternatively, the snare sound is obtained with wires or guitar strings placed against the inside surface of the front panel, and these rattle when the panel is struck. Measurements of acoustic transfer functions with impulse excitation and roving hammer structural measurements explore the acoustic and structural resonances of the cajon with rattling strings removed. Spectra from recordings establish timbral features of the instrument, both with and without the rattling strings. By comparing results from measurements and recordings, the important features of the particular instrument tested in this study are identified, and possible directions for improved the designs are suggested.

9:30

5aMU5. Improving reliability of measurement algorithms in differentiated electroglottograph and audio signals. Shonda Bernadin (Elec. and Computer Eng., Florida A&M University-Florida State Univ. College of Eng., 2525 Pottsdamer St., Tallahassee, FL 32310, bernadin@eng.fsu.edu) and Richard Morris (Speech and Commun. Disord., Florida State Univ., Tallahassee, FL)

The purpose of this work was to develop an optimized algorithm for determining the closed quotient (CQ) measurements of the vocal folds of female singers. This study extends previous results which showed that the measurement algorithm for differentiated electroglottograph (dEGG) signals and differentiated audio (dAUDIO) signals gave moderately reliable results with a correlation coefficient of $r = 0.79$. Additional performance studies indicate that the reliability may be improved by combining the differential signals and modifying the measurement algorithm to reduce the amount of signal overlap. Preliminary results using the modified measurement algorithm yield a significant increase in the correlation coefficient ($r = 0.83$). This works contributes to the development of a computational framework for determining accurate and reliable measurements for characterizing register shifts through an octave in female singers using electroglottography.

9:45

5aMU6. Impact of acoustic resonances on overtone correlations across a large musical instrumental database. Sarah R. Smith and Mark F. Bocko (Univ. of Rochester, 405 Comput. Studies Bldg., P.O. Box 270231, Rochester, NY 14627, sarahsmith@rochester.edu)

When performers use vibrato, the pitch and intensity of the note is modulated in order to create an expressive effect. Although one might expect that vibrato would produce a proportional frequency modulation in each of the overtones, this is not always the case. Past work has shown that the instantaneous frequencies of some instruments, particularly bowed strings, tend to exhibit reduced overtone correlation when performed with vibrato. Additionally, the presence of reverberation in a recording has been shown to reduce the correlation between overtones for many instruments. In this study, we present an analysis of overtone correlations for a wide range of instrument sounds taken from multiple large databases. Using this large library of tones, we illustrate the effect of instrument resonators on these correlations for tones performed both with and without vibrato.

10:00–10:15 Break

10:15

5aMU7. Complex point source model to calculate the sound field radiated from musical instruments. Tim Ziemer and Rolf Bader (Inst. of Systematic Musicology, Univ. of Hamburg, Neue Rabenstr. 13, Hamburg 20354, Germany, tim.ziemer@uni-hamburg.de)

A simple method is described to record the radiated sound of musical instruments and to extrapolate the sound field to distances further away from the source. This is achieved by considering instruments as complex point sources. It is demonstrated that this simplification method yields plausible results not only for small instruments like the shakuhachi but also for larger instruments such as the double bass: The amplitude decays in a given manner and calculated interaural signal differences reaching the listener decrease with increasing distance to the source. The method is applied to analyze the sound radiation characteristics as well as the radiated sound field in a listening region regardless of room acoustical influences. Furthermore, it has been implemented in a psychoacoustic wave field synthesis system to generate the impression of a certain source width. Implementations in terms of room acoustical simulations, spatial additive synthesis and sound field synthesis are discussed.

10:30

5aMU8. Stroboscopic illumination for electronic speckle pattern interferometry. Colin Gavin and Steve Tufte (Dept. of Phys., Lewis & Clark College, MSC 15, 0615 SW Palatine Hill Rd., Portland, OR 97219, tufte@lclark.edu)

A common realization of holographic interferometry is called Electronic Speckle Pattern Interferometry (or ESPI)—a technique capable of measuring harmonic modes of vibrating objects. We present a method of improving the contrast and quality of fringe patterns recorded with a simple, table-top ESPI system. In particular, by using stroboscopic illumination generated by an optical chopper, we are able to produce fringes that follow a cosine pattern, rather than the Bessel pattern fringes that result from time averaging. Since Bessel function amplitudes rapidly decrease for subsequent maxima, the stroboscopic cosine fringes show much better contrast. Also, because the zeros of cosine fringes are evenly spaced, it is much simpler to interpret the images to extract quantitative deformation amplitudes. We show that our results agree well with the theoretical predictions. This system was developed for use in musical acoustics research as a Senior Thesis project by an undergraduate student (Gavin). This low-cost, simple modification of the commonly used ESPI system could benefit other colleges and universities using holographic interferometry for acoustics research.

10:45

5aMU9. An experimental modal analysis on the coimbra model of the Portuguese guitar. Octávio Inácio and Rui Ribeiro (ESMAE, Rua da Alegria, 503, Porto 4000-053, Portugal, octavioinacio@esmae.ipp.pt)

The most distinctive Portuguese traditional music style is Fado. In this form of Portuguese music, a singer is accompanied by two instruments: a classical guitar and a pear shaped plucked chordophone with six courses of double strings—the Portuguese guitar. There are two distinct types of this instrument—the Lisbon and the Coimbra models—named after the towns where the two different styles of Fado have developed. These guitars differ basically on their size and tuning, both comprising 6 orders of double steel strings, while the construction method (strutting patterns, wood species used, and soundboard thickness distribution) vary for different builders. As part of an ongoing research project that investigates the vibroacoustical behavior of this instrument for different types of designs, an experimental modal analysis of a fully assembled Coimbra guitar was performed. In this work, we present the results of this analysis showing the main characteristics of the frequency response curves and significant vibratory modes as compared to other similar plucked-string instruments.

11:00

5aMU10. Timbre aspects of ride cymbals: Sound coloration analysis using psychoacoustics models and subjective evaluation. Kauê Werner, Erasmo F. Vergara, Stephan Paul, and Júlio A. Cordioli (Lab. of Acoust. and Vib., UFSC, Acari Silva 74, Casa 3, Florianopolis, SC 88035440, Brazil, kaue.werner@lva.ufsc.br)

The timbre of a musical instrument is a multidimensional variable that relies on the complexity of human perception. So far, there are only a few studies concerning the timbre of percussion instruments. The sound characteristics of cymbals depend on geometry, material, ways of playing, and so on. On the perceptive side, sound coloration is one of the dimensions most used by musicians with regard to compare the timbre of Ride Cymbals. In order to get insight into the perception of the sound of Ride Cymbals, subjective evaluations of recorded cymbal sounds were carried out, using bipolar rating scales. Psychoacoustic models, such as Sharpness and Tonality, were also used to analyze the sound signals. Based on subjective and objective evaluations, linear regression models were proposed to quantify perceptive dimensions such as brightness and darkness. The coefficients of determination indicate that this kind of model can be used as a feasible way to represent sound coloration in Ride Cymbals.

11:15

5aMU11. Construction of a Finite Element Model of the Japanese *koto* and its comparison with the reference instrument. A. Kimi Coaldrake (Music, Univ. of Adelaide, Elder Conservatorium of Music, Adelaide, SA 5005, Australia, kimi.coaldrake@adelaide.edu.au)

As a first step toward developing a generic model of the Japanese *koto* (13 string plucked zither) and related Asian zithers to understand the physical characteristics of the instruments and how they contribute to the overall sound quality, a finite element model of the *koto* was constructed. Samples of paulownia wood from a reference instrument were examined by SEM to establish the physical properties of this less well-characterized wood. The model was validated against the chladni patterns of Ando's 1986 experiments. Eigenfrequencies and mode shapes were calculated before coupling the instrument to a sphere of air. Frequencies corresponding to the standard tuning of the 13 strings were applied at the same point where plucking normally occurs. A steady state response of the instrument was recorded that showed standing waves within the cavity of the instrument. Frequency scans were also undertaken. Finally, the transient response of the model to the string frequencies were measured and compared with the playing of the reference instrument. Overall, the model predicts the main features and some subsidiary ones of the reference instrument and point to directions for future work for characterizing the sound quality of the *koto*.

11:30

5aMU12. Timbre maps to characterize the sound quality of the Japanese *koto*. A. Kimi Coaldrake (Music, Univ. of Adelaide, Elder Conservatorium of Music, Adelaide, SA 5005, Australia, kimi.coaldrake@adelaide.edu.au)

The Japanese *koto* and related zithers in East Asia are known for their distinctive sound quality (timbre), but the precise origins of the characteristics remain elusive. In an attempt to extend the knowledge of these characteristics, a finite element model of the Japanese *koto*(13 string plucked zither) was constructed using Comsol Multiphysics 5.1 based on a *koto* of known provenance and parameters. A series of experiments to identify the acoustical properties of the instrument were compared against results of the model. The results were then collated into a series of timbre maps to establish patterns of responses. This included overlaying eigenfrequencies, individual peaks from the spectra of the thirteen strings for the standard (*hirajō shi*) tuning, hidden peaks identified by the fourth derivative frequency scans and spectra from mechanical tapping of the reference instrument. The study shows that the anisotropy of the paulownia wood of the *koto* plays an important role in the vibration modes and frequency response spectrum. The timbre maps then identifies characteristics of the non harmonic responses that contribute to the *koto*'s distinctive sound and provide a template for the study of sound quality associated with culturally specific timbral preferences for East Asian zithers.

FRIDAY MORNING, 6 NOVEMBER 2015 GRAND BALLROOM 1, 9:00 A.M. TO 10:00 A.M.

Session 5aNS

Noise: Noise Potpourri

Scott D. Sommerfeldt, Chair
Dept. of Physics, Brigham Young University, N181 ESC, Brigham Young University, Provo, UT 84602

Contributed Papers

9:00

5aNS1. Development of open air sound barrier system using single microphone and speakers. Natsuki Takao (School of Sci. for Open and Environment Systems, Keio Univ. Graduate School of Sci. and Technol., Hiyoshi 3-14-1, Kohoku-ku, Yokohama 223-8522, Japan, n.takao@z6.keio.jp)

Music players usually build soundproof rooms in their houses. These rooms prevent noise problems among their neighbors when they practice at home. However, in soundproof rooms, vibrancy of musical sound is often lost, and music players feel as if the sound is cooped-up. Besides, installation cost of a soundproof room is usually high. We therefore aim to create a new sound barrier system. This system produces soundproof space in the open air by using single microphone and adequate number of speakers. The speakers cancel propagating waves which come from the musical instruments by outputting antiphase waves. The sound is muffled in the half sphere surrounding the player. Thus, the player can listen to their sound without losing vibrancy, while sound leakage outside the system is suppressed. Antiphase waves are predicted based on the wave equation with the signal picked up by the microphone as the boundary condition. In this presentation, a simulation for determination of the adequate number and position of the speakers is presented. Then, experimental validation is discussed in detail.

9:15

5aNS2. Studying of the noise sources in a pneumatic nail-gun process. Zahra Nili Ahmadabadi, Frédéric Laville, and Raynald Guilbault (Mech. Eng., Université du Québec, École de technologie supérieure, 1100 Rue Notre-Dame Ouest, Montreal, QC H3C 1K3, Canada, zahra.nili-ahmadabadi.1@ens.etsmtl.ca)

Despite generating high noise levels responsible for hearing loss among workers, nail-guns have been used to connect wood pieces since the 50s. The present study belongs to a broader investigation aiming to reduce noise emissions in nail-guns. This noise reduction objective may be achieved by a nail-gun concept design improvement. This requires a study of the noise sources in time domain. The study uses an advanced measurement setup to identify the existing noise sources and their causes in each time interval. The setup includes nine microphones, two accelerometers, two pressure transducers, and a high-speed camera. Three major noise sources were identified during the nailgun process: the air exhaust, the body of the machine, and the workpiece. The air exhaust noise is radiated from the air exhaust holes mostly before the nail driving operation and during the air exhaust process. The noise radiated from the body of the machine is caused by vibrations of different internal/external parts of the machine and air movements. It persists almost throughout the whole duration of the nailgun process. Finally, the workpiece noise is radiated from the vibrating workpiece starting simultaneously with the nail driving operation and ending before the start of the air exhaust process.

9:30

5aNS3. Improved ear simulator for extended application range. Per Rasmussen (G.R.A.S. Sound & Vib. A/S, Skovlytoften 33, Holte 2840, Denmark, pr@gras.dk), Jacob Soendergaard (G.R.A.S. Sound & Vib. NA, Twinsburg, OH), and Morten Wille (G.R.A.S. Sound & Vib. A/S, Holte, Denmark)

The international standard IEC 60318-4 specifies an occluded ear simulator for testing headphones, earphones, hearing protectors, hearing aids etc. The standard specifies a specific microphone type which limits the dynamic range of the coupler, such that it is not possible to measure very low levels or very high levels. Additionally, the standard 711 coupler is often interfaced to a pinna simulator incorporated in a Head and Torso simulator as per IEC 60318-7. This interface has traditionally been implemented as a cylindrical, straight ear canal simulator. This makes the fit of many modern in-ear headphones and hearing protectors problematic and unrealistic. By using low noise microphones instead of the standard microphones, the coupler can be used for measuring extremely low sound pressure levels such as noise floor, low level distortion or microphonics. Conversely, by using low sensitivity microphones, the coupler can be used for extremely high level measurements—useful for testing active and passive attenuation ratings of hearing protectors. Moreover, using a vast database of 3D human ear canal scans, a new pinna and ear canal simulator is proposed that will greatly improve measurement accuracy and repeatability on products going on or in the ear.

9:45

5aNS4. Modeling of acoustic resonators and resonator arrays with non-ideal geometries. Matthew F. Calton and Scott D. Sommerfeldt (Brigham Young Univ., N306 ESC, Provo, UT 84602, mattcalton@gmail.com)

Acoustic resonators offer stable, cost-effective attenuation for many noise control applications. Due to their widespread use in engineering and physics, analytical expressions with varying degrees of accuracy have been obtained to predict performance. However, most of the existing formulations are limited to ideal geometries with sharp transitions between two regions. Practical applications of these acoustic resonators often involve space limitations that necessitate curved segments and gradual transitions. This research aims to better characterize the response of non-ideal geometry acoustic resonators. Using currently available expressions for duct bends, the acoustic impedance of bends with various angles and lengths is determined, in an effort to develop relatively simple models for incorporating such elements in a resonator. Other non-ideal geometries as they relate to Helmholtz resonators and arrays of resonators are also explored. These calculations are compared to experimental impedance measurements for validation of the model.

FRIDAY MORNING, 6 NOVEMBER 2015 CLEARWATER, 8:00 A.M. TO 11:45 A.M.

Session 5aPA

Physical Acoustics: General Topics in Physical Acoustics II

Michael R. Haberman, Chair
Applied Research Laboratories, The University of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758

Contributed Papers

8:00

5aPA1. Study of Wigner crystal in n-GaAs/AlGaAs by surface acoustic waves. Alexey V. Suslov (NHMFL, Florida State Univ., 1800 E. Paul Dirac Dr., Tallahassee, FL 32310, suslov@magnet.fsu.edu), Irina L. Drichko, Ivan Y. Smirnov (A. F. Ioffe PTI of RAS, St.-Petersburg, Russian Federation), Loren N. Pfeiffer (Elec. Eng., Princeton Univ., Princeton, NJ), Ken W. West (PRISM, Princeton Univ., Princeton, NJ), and Yuri M. Galperin (Depertment of Phys., Univ. of Oslo, Oslo, Norway)

The surface acoustic wave (SAW) technique was used for studying a 65 nm wide GaAs quantum well containing a two dimensional electron system (2DES) with the density of $5{\cdot}10^{10}$ cm^{-2} and the mobility of $8{\cdot}10^{6}$ cm^2/V·s. A SAW propagated in proximity of the quantum well. Both SAW attenuation α and SAW velocity V were measured in perpendicular magnetic field of up to 18 T in the frequency f range 28.5–306 MHz at temperatures 40–380 mK. Then, both real and imaginary parts of the ac conductance $\sigma(f) = \sigma_1(f) + i{\cdot}\sigma_2(f)$ of the 2DES were calculated from α and V. Dependencies of α, V, σ_1, and σ_2 on magnetic fields showed a rich oscillation pattern, in particular, the fractional quantum Hall effect (FQHE). Thus, at low temperature, the FQHE state was observed at the filling factor $\nu = 0.20$, whereas, in vicinity of this value, at $\nu = 0.19$ and 0.21, the 2DES behaved as a 2D Wigner crystal weakly pinned by a disorder random potential. The calculated pinning frequencies at high and zero magnetic fields were 193 MHz and 12.4 GHz, respectively, and the correlation length of the random potential was 10^{-2} cm. [Work supported by RFBR 14-02-00232, NSF DMR-1157490, the State of Florida, the Gordon and Betty Moore Foundation GBMF2719, and NSF MRSEC-DMR-0819860.]

8:15

5aPA2. The acoustic study of soil liquefaction effects in-situ. Andrey Konkov, Andrey Lebedev, and Sergey Manakov (Geophysical Acoust., Inst. of Appl. Phys., 46 Ul'yanov St., Nizhny Novgorod 603950, Russian Federation, magister44@yandex.ru)

This study is aimed to describe effects of saturation with water on soil stiffness and bonds strength. Linear and nonlinear soil acoustic characteristics as dependent on saturation have been studied in-situ. At the end of experiment, the soil became unstable that allowed tracking the saturation process as a whole. The experiment was prepared as follows. Two weeks before the experiment fulfilment, the trench was dug and a hose with holes was embedded. The hose was connected to the water supply network through the water meter. During saturation, the soil acoustic responses were being continuously recorded. The soil linear stiffness has been measured by remote technique based on the analysis of the dispersion of Rayleigh wave polarization. The measurements were carried out by pairs of vertically and horizontally oriented geophones. Then, the bulk stiffness and the Poisson's ratio profiles were reconstructed. Special attention was given to the assessment of its nonlinear parameters. Effects of hysteresis nonlinearity in dependence "force versus displacement" were observed and discussed as well. The force and displacement were measured by two accelerometers mounted on the baseplate and the reaction mass of vibrational source. [The work was

partially supported by RFBR, research projects No.14−02−00695, 15−05−08196, 15−45−02450, and 14−05−31249.]

8:30

5aPA3. Scattering by a thin and flat elliptic object: How the conformal mapping approach allows addressing numerical issues. Didier Cassereau (Laboratoire d'Imagerie Biomédicale, 15 rue de l'Ecole de Médecine, Paris 75006, France, didier.cassereau@upmc.fr), Fabien Mézière, Marie Muller, Emmanuel Bossy, and Arnaud Derode (Institut Langevin, Paris, France)

In this work, we are interested in modeling the propagation of an ultrasonic field in the complex trabecular bone structure. For this purpose, we use a simplified formulation, based on a representation of the bone tissue as thin and flat elliptic scatterers. With an ultrasonic inspection frequency of 1 MHz, the largest dimension of the ellipse is about half a wavelength, while the smallest dimension is 7–10 times smaller. The computation of the scattered field is based on a modal decomposition, generalized to the case of scatterers of arbitrary geometry (Chati *et al*., "Modal theory applied to the acoustic scattering by elastic cylinders of arbitrary cross section," J. Acoust. Soc. Am. **116**, 2004). Due to the very thin and flat geometry, this approach suffers huge numerical difficulties that require the use of enhanced precision and very long computation times. In this paper, we illustrate these issues. An alternative has been proposed (Liu *et al*., "Conformal mapping for the Helmholtz equation: Acoustic wave scattering by a two dimensional inclusion with irregular shape in an ideal fluid," J. Acoust. Soc. Am. **131**, 2012), based on a conformal mapping of the ellipse. We compare the two formulations and show how the conformal mapping allows reducing drastically the numerical issues resulting from the standard approach.

8:45

5aPA4. Parametric study of an ultrasonic non-destructive testing problem based on the reciprocity principle and a hybrid numerical method. Florian Lyonnet, Didier Cassereau (Laboratoire d'Imagerie Biomédicale, Laboratoire d'Imagerie Biomédicale, Paris, France, florian.lyonnet@upmc.fr), and Marie-Françoise Cugnet (AREVA NP, Ugine, France)

Numerical simulations are needed for both the design and the improvement of Ultrasound Non-Destructive Testing techniques in industry. One typical configuration is the pulse echo immersion testing of a material with a possible crack. This is a large and multiscale elastodynamic problem, for which the computation may be intensive using standard discrete methods. Different approaches have been proposed to gain efficiency in terms of the computation time, as i) the hybridization of a discrete method with a semi-analytical formulation or ii) using the reciprocity principle to separate the calculation of the field radiated by the crack from the field in the same material. We present a numerical strategy based on those two approaches in order to perform 3D simulations with a possible parametrization of the crack geometry and location. First, the Spatial Impulse Response (SIR) of a focalized transducer in water is computed using a semi-analytical software. Then, we show that the calculation of the SIR can be pursued in the same elastic material using a FDTD method. To take into account the effects of the crack, this SIR is used in conjunction with the time domain reciprocity equation. This process allows performing an efficient computation of the echo signal from the crack. Results and comparisons with experimental measurements will be presented in a 2D case.

9:00

5aPA5. Calculation of vibrational mode contributions to sound absorption in excitable gases by decomposing multi-relaxation absorption curve. Ke-Sheng Zhang (School of Information Eng., Guizhou Inst. of Technol., 1st, Caiguan Rd., Yunyan District, Guiyang, Guizhou 550003, China, keshengzhang@163.com), Ming Zhu (School of Electron. Information and Communications, Huazhong Univ. of Sci. and Technol., Wuhan, China), Chun Li (Library, Guizhou Inst. of Technol., Guiyang, China), and Weihua Ou (School of Mathematics and Comput. Sci., Guizhou Normal Univ., Guiyang, China)

Molecular vibrational relaxation is responsible for the sound relaxational absorption in most excitable gases. However, it is desirable to calculate the contribution of each vibrational mode to sound multi-relaxation absorption. In this paper, first, a sound multi-relaxation absorption curve is decomposed into the sum of single-relaxation curves; second, based on this decomposed characteristic, a model to quantitatively analyze the vibrational mode contributions to sound absorption is proposed. The simulation results quantitatively demonstrates that the primary relaxation process connected with the lowest mode is the decisive factor for sound relaxational absorption, and the mode with lower vibrational frequency supplies higher contribution to the primary relaxation process in pure polyatomic gases.

9:15

5aPA6. Measurement of tortuosity and viscous characteristic length of double-layered porous absorbing materials with rigid frames via transmitted ultrasonic wave. Mustapha Sadouki (Département de Sci. de la Matière, Université Djilali Bounaama à khemis-miliana, Rte. Thenia el Had, Ain Defla, Khemis-miliana 44225, Algeria, mustapha.sadouki@univ-dbkm.dz), Amine Berbiche (Fac. de Physique, USTHB, Algiers, Bab Ezzouar, Algeria), Mohamed fellah (Fac. de Physique, USTHB, Alger, Algeria), Zine El Abidine fellah (LMA UPR7051 CNRS Aix-Marseille Univ, Centrale Marseille, Marseille, France), and Claude Depollier (Laboratoire d'Acoustique de l'Université du Maine UFR STS, LUNAM Université du Maine, UMR CNRS 6613, Le Mans, France)

In this work, an indirect method is proposed for measuring simultaneously acoustic parameters describing the ultrasonic propagation in double-layered porous medium. The porous media consist of two slabs of homogeneous isotropic porous materials with a rigid frame. Each porous slab is described by equivalent fluid model, in which the acoustic wave propagates only in the fluid saturating the material. The inverse problem is solved numerically using experimental transmitted waves in time domain. Four parameters are inverted: tortuosity and viscous characteristic lengths of the two layers. Tests are performed using industrial plastic foams. Experimental and numerical validation results of this method are presented.

9:30

5aPA7. Acoustic transmission from a single crystal layer of nonlinear resonators in a soft elastic matrix. Nicolas Viard and Nicholas Fang (Mech. Eng., Massachusetts Inst. of Technol., 77 Massachusetts Ave., Cambridge, MA 02139, nviard@mit.edu)

Ultrasound transmission measurements of a single crystal layer of identical nonlinear resonators are reported for frequencies under 1 MHz. The resonators are spherical gas-filled cavities embedded in a soft elastic matrix. The cavities are formed by injection of gas through a capillary tube in a polymer solution right before it cures. Sample characteristics such as the size or the spacing between the cavities are adjusted by varying the injection parameters. Typical size for the cavities ranges from 100 μm to 1 mm. The sample is immersed in water where transmission measurements are conducted. As allowed by acoustic transducer, amplitude and phase of the wave is measured in transmission as a function of the frequency and the amplitude of the initial incident pulse.

9:45–10:00 Break

10:00

5aPA8. Stress and energy transmission by inhomogeneous plane waves into dissipative media. Daniel C. Woods, J. Stuart Bolton, and Jeffrey F. Rhoads (School of Mech. Eng., Purdue Univ., 585 Purdue Mall, West Lafayette, IN 47907, woods41@purdue.edu)

The characteristics of sound transmission into real, or dissipative, media differ from those of transmission into lossless media. In particular, when a plane wave in a fluid is incident upon a real, dissipative elastic material, the transmitted waves are in general inhomogeneous, even when the incident wave is itself homogeneous and incident at a sub-critical angle; and more significantly, energy transmission occurs even above the critical angle. In addition, for any real incidence angle, the parameters of an incident inhomogeneous wave may be tuned so that there is no reflection from the surface of a viscoelastic solid. That phenomenon may be exploited in applications requiring energy transmission into solids. In this work, the transmission of incident inhomogeneous, as well as homogeneous, acoustic waves into solid materials is characterized; a hysteretic damping model is assumed. Numerical results are presented for the transmitted stress and energy distributions

for typical solid materials, including polymer-based solids. The conditions for total transmission, i.e., no reflection at the interface, are explored, where the propagation angle, degree of inhomogeneity, and frequency of the incident wave are varied for a given material. These investigations show substantial transmission gains in the vicinity of the zero of the reflection coefficient, compared to homogeneous incident waves.

10:15

5aPA9. Standoff photoacoustic spectroscopy for hazard detection. Logan S. Marcus, Ellen L. Holthoff, and Paul M. Pellegrino (Sensors and Electron Devices Directorate, U.S. Army Res. Lab., 2800 Powder Mill Rd., RDRL-SEE-E, Adelphi, MD 20783, loganmarcus@gmail.com)

Photoacoustic spectroscopy (PAS) is a versatile and sensitive chemical sensing method. This versatility allows for the construction of a variety of sensors that are optimized for specific sensing tasks. Current research at the U.S. Army Research Laboratory (ARL) is focused on the development of a standoff hazardous materials detection technique based on an interferometric sensor. The standoff detection paradigm increases operator safety and reduces sample preparation requirements as compared to traditional photoacoustic cell-based sensors. We demonstrate the collection of photoacoustic spectra of layered solid samples at a standoff distance of one meter. The layered samples are constructed via deposition of a thin layer of energetic or other hazardous substance upon a thick substrate. We will also discuss excitation source selection as it relates to the operating mode of the source (i.e., pulsed or continuous wave (CW) modulated).

10:30

5aPA10. A self consistent theory for phonon propagation in a suspension of one-dimensional filaments. Douglas Photiadis (NRL, 4555 Overlook Ave. SW, Washington, DC 20375, douglas.photiadis@nrl.navy.mil)

Using a self consistent, field theoretic multiple scattering theory in a viscous, acoustic fluid, we have developed a mean field model to describe the propagation of phonons in suspensions of one dimensional filaments. This geometry is approximately realized by the cytoskeleton in generic cells and can be studied in a controlled manner using suspensions of carbon nanotubes. We have extended the coherent potential approximation method, typically used for point scatterers, to the case of one dimensional filaments using the supersymmetric method, an approach employed with great success in disordered electronic systems. Unlike similar systems involving suspensions of effectively point scatterers, viscosity is found to play an important role in determining the observed wave speed because of both the high density and the one dimensional nature of the scatterers. We have carried out Brillouin light scattering measurements on both live cells, for which we believe the observed frequency shifts result from coupling to the cytoskeleton, and carbon nanotube suspensions. By varying the temperature, we may approach the glass transition of the fluid and substantially change the viscosity to directly test our predictions. Preliminary measurements show frequency shifts in accord with the predictions. [Research funded by the Office of Naval Research.]

10:45

5aPA11. Cost-effective potential application of acousto-optic Bragg imaging of biological tissue. Alem Teklu (Phys. & Astronomy, College of Charleston, 9 Liberty St., Charleston, SC 29424, teklua@cofc.edu), Nico Declercq (Georgia Inst. of Technol., Metz, France), and Michael McPherson (Div. of Natural Sci., Northwest MS Community College, Senatobia, MS)

Acousto-Optic Bragg Imaging is a technique that uses the interaction of light with ultrasound to optically image obstructions in acoustical fields. Existing reports of Acousto-Optic Bragg Imaging based on transmission of acoustic fields through obstructions exhibit strong acoustic impedance mismatches manifested by poor image quality and missing details of physical structures of obstructions. In this work, the image quality was improved to exhibit detailed physical structures of an object by using an improved Bragg imaging system. This project investigates the possibility of extending an acoustic Bragg imaging technique in transmission mode to image animal or plant tissues; a small Azalea leaf is used as an illustration in this case. The Bragg image produced clearly shows the veins of the vascular azalea leaf serving as a proof of concept for cost-effective potential application of acoustic Bragg imaging of biological objects in the medical field. Moreover, acousto-optic Bragg imaging is potentially harmless to biological cells and is sensitive to density and elastic variations in the tissue.

11:00

5aPA12. Acoustical activity of lithium niobate crystals. Farkhad R. Akhmedzhanov (Samarkand State Univ., 15 University Blvd, Samarkand 140104, Uzbekistan, farkhad2@yahoo.com)

Acoustical activity in Lithium Niobate crystals was investigated by method of Bragg light diffraction. Transverse acoustic waves were excited in the range of 0.4–1.6 GHz using quartz piezoelectric plates. $LiNbO_3$ samples were oriented at small angles to the axis Z in the crystallographic plane (010). Specific rotation of the polarization plane of transverse waves was determined from the dependence of the intensity of the diffracted light of the distance from the piezoelectric transducer along the acoustic wave propagation. The observed large specific rotation of the polarization plane of the acoustic waves can be used in devices controlling the intensity of light by the phenomenon of acoustical activity. Components of the imaginary part of the generalized Christoffel tensor taking into account the spatial dispersion have been determined also. It is shown that in crystals of class 3m the imaginary components of the Christoffel tensor for all the directions in the symmetry plane (100) are zero.

11:15

5aPA13. Reflected wave by the first interface of rigid porous medium at Darcy's regime. Mustapha Sadouki (Departement de Sci. de la matière, Université Djilali Bounaama à khemis-miliana, Rte. Thenia el Had, Ain Defla, Khemis-miliana 44225, Algeria, mustapha.sadouki@univ-dbkm.dz), Zine El Abidine Fellah (LMA UPR7051 CNRS Aix-Marseille Univ, Centrale Marseille, Marseille, France), Mohamed Fellah (Fac. de Physique, USTHB, Alger, Algeria), and Claude Depollier (Laboratoire d'Acoustique de l'Université du Maine UFR STS, LUNAM Université du Maine, UMR CNRS 6613, Le Mans, France)

In this paper, reflection waves by the first interface of porous medium having rigid frame is considered. The method presented in this work is based on a temporal model of the direct problem in which a simplified expression of the reflection coefficient at the Darcy's regime (low frequency range) is established using equivalent fluid model, this expression depends only on the porosity and the viscous permeability (or the flow resistivity) of the medium. The simulated reflected wave is obtained in time domain by convolution between the reflected operator and the incident field. Experimental results are given for samples of air-saturated plastic foams and compared with theoretical predictions.

11:30

5aPA14. Characterization of rigid porous medium via ultrasonic reflected waves at oblique incidence. Mustapha Sadouki (Departement de Sci. de la matière, Université Djilali Bounaama à khemis-miliana, Rte. Thenia el Had, Ain Defla, Khemis-miliana 44225, Algeria, mustapha.sadouki@univ-dbkm.dz), Amine Berbiche, Mohamed fellah (Fac. de Physique, USTHB, Alger, Algeria), Zine El Abidine fellah (LMA UPR7051 CNRS Aix-Marseille Univ, Centrale Marseille, Marseille, France), and Claude Depollier (Laboratoire d'Acoustique de l'Université du Maine UFR STS, LUNAM Université du Maine, UMR CNRS 6613, Le Mans, France)

In this paper, an enhanced method is proposed for measuring porosity, tortuosity, viscous, and thermal characteristic length of porous materials having a rigid frame via reflected ultrasonic waves at oblique incidence using the equivalent fluid model. The advantage of the proposed method is that the four parameters are determined simultaneously just using reflected experimental waves for a porous material saturated by air. The inverse problem is solved based on the least-square numerical method using experimental reflected waves in time domain. Tests are performed using industrial plastic foams. Experimental and numerical validation results of this method are presented.

Session 5aSA

Structural Acoustics and Vibration: General Topics in Structural Acoustics and Vibration

Stephen Oregan, Chair
Naval Surface Warfare Center, Carderock Division

Contributed Papers

8:30

5aSA1. Active and passive techniques for a cost-effective noise reduction in the interior of aircraft cabins. Hasson M. Tavossi (Phys., Astronomy, and GeoSci., Valdosta State Univ., 2402, Spring Valley Cir, Valdosta, GA 31602, htavossi@valdosta.edu)

Different noise reduction techniques that can be applied to the interior of aircraft cabin are investigated, to determine the most cost-effective means, without any aircraft external modifications, such as jet engine design change, or fuselage modifications, with no significant added weight. The goal of this research is to arrive at a cabin interior design that can be retrofitted to the existing aircraft interior to reduce overall cabin noise. Relaxation oscillations of the aircraft cabin model, considered as a system in forced vibrations with non-linear damping, and sub-harmonic resonances are considered. Negative and positive damping coefficients, and some techniques for noise cancelation by active means are discussed. From noise power-spectrum results for a typical aircraft cabin, amplitude versus audible frequency, one can determine the most energetic cabin vibration modes. Those modes require the highest damping. The proposed technique will utilize a regular matrix of the multiple sets of open Helmholtz resonators, with sound absorbing surfaces, that are imbedded in the cabin interior walls, just below the surface, and tuned to the highest noise level frequencies inside the cabin. The resonators dissipate the noise energy inside the aircraft at the most dominant frequencies, and hence reduce the overall cabin noise level.

8:45

5aSA2. Numerical hybrid TMM-modal finite element method prediction of the vibroacoustic of sandwich panels with add-on damping. Imen Rzig, Noureddine Atalla, and Dilal Razhi (Mech., univesité de Sherbrooke, E3-2115, 2500 Boulvard de l'université, Sherbrooe, QC J1K2R1, Canada, imen.rzig@usherbrooke.ca)

This paper discusses the numerical modeling of the vibroacoustic response of sandwich-composite panels with add-on damping, under a diffuse acoustic field (DAF) excitation. A modal synthesis approach is used for the calculation of the structural response and the Rayleigh's integral is used for the acoustic response. Since the panel has a viscoelastic core, a methodology is presented to handle efficiently the modeling of the frequency depended properties of the viscoelastic layer. A hybrid TMM-modal FEM method is used to predict the acoustic response at high frequency, using the equivalent damping of panel which are calculated from strain energies. Next, a parameters study on the effect of the viscoelastic layer location is presented. In particular, three locations are compared: within the Honeycomb core, within the skins and added to the skin with a constraining layer. The effects of the excitation type on the vibration and acoustic response are also discussed. Key words: Sandwich NIDA, Modal FEM method, TMM method, viscoelastic damping, acoustic response, equivalent properties.

9:00

5aSA3. A modal solution for finite length rods with non-uniform area. Andrew J. Hull (Naval Undersea Warfare Ctr., 1176 Howell St., Newport, RI 02841, andrew.hull@navy.mil)

This talk derives a modal solution to the displacement field of a finite length rod whose area is varying with respect to its length. This method facilitates a solution to any problem where the area and derivative of the area can be represented as analytical functions. The problem begins by writing the longitudinal displacement of the non-uniform area rod as a series of indexed coefficients multiplied by the eigenfunctions of the uniform area rod. This series solution is inserted into the non-uniform area rod equation, multiplied by a single p-indexed eigenfunction and integrated over the interval of the rod. The resultant expressions can be written as a set of linear algebraic equations and this yields a solution to the displacement of the system. Five example problems are included: the first one has a non-uniform area that corresponds with a known analytical solution, the second has an area that can be represented by a Fourier series, and the third and fourth have areas that do not have a known analytical solution and the fifth is a generic second order non-constant coefficient differential equation. Four of these problems are verified with other methods. Convergence of the series solution is discussed.

9:15

5aSA4. Remote acoustic sensing of mechanical changes in thin vibrating plates. Tyler J. Flynn and David R. Dowling (Mech. Eng., Univ. of Michigan, 1231 Beal Ave., Rm. 2010, Ann Arbor, MI 48109, tjayflyn@umich.edu)

Remote measurements of radiated sound from a vibrating structure may be exploited for non-contacting structural health monitoring. In this work, an experimental method for remote acoustic sensing of mechanical changes in thin vibrating plates is presented. The basic concept is to compare the radiated sound from baseline and mechanically modified plates to determine the presence or absence of mechanical modifications. Experimental results are presented for measurements of radiated sound from a 0.3-m-square by 1.6-mm-thick aluminum plate with clamped edges subject to swept-frequency shaker base-excitation in the bandwidth from 100 Hz to 4 kHz. The primary mechanical change considered in this investigation is added mass via magnets. Acoustic signals are collected with a linear array of sixteen microphones and are used to characterize the acoustic radiation from baseline and modified vibrating plates, to determine the thresholds above which mechanical changes can be reliably detected with statistical significance. This binary method of non-destructive evaluation can be extended to other classes of defects, such as holes, cuts (simulated cracks), and changes in the boundary conditions. With the integration of more advanced signal processing techniques, localization of the mechanical changes may be possible as well. [Sponsored by NAVSEA through the NEEC.]

9:30

5aSA5. The effect of elastic point contact: theory and experiment. Douglas Photiadis and David Goldstein (NRL, 4555 Overlook Ave. SW, Washington, DC 20375, douglas.photiadis@nrl.navy.mil)

It has recently been pointed out that nearfield deformation in the neighborhood of an elastic point contact can have significant phenomenological effects, producing shifts of resonance frequencies and serving as a source of loss. In order to take these effects into account, it is necessary to employ three dimensional elasticity theory, precluding the use of lower dimensional dynamic models, for example, plate elements in a finite element analysis (FEA) computation. This is a very significant limitation because the frequency response of many large complex structures can only be predicted using such models. We propose here a theoretical modeling approach that resolves this problem and enables the use of lower dimensional models in the analysis of such systems. We have found the predictions of the model to be in good agreement with experimental measurements in the cases we have examined so far, translational and cantilever resonators. Research funded by the Office of Naval Research.

9:45

5aSA6. Calculation of energy exchange between the outer hair cell and structural components of the organ of Corti, using the *in vivo* measurement data. Amir Nankali and Karl Grosh (ME Dept., Univ. of Michigan, Ann Arbor, MI 48105, nankali@umich.edu)

The mammalian cochlea amplifies the sound born vibration of the microstructures of the OoC through a frequency and level dependent active process. The somatic motility of the mechanosensory outer hair cells (OHCs) is hypothesized as the key element of the cochlea active mechanism. During the sound stimulation, the OHCs respond to the membrane potential fluctuation through a fast alteration of their length. This cellular length change applies an active harmonic force to both sides of the OHC (reticular lamina (RL) on the apical part and basilar membrane (BM) on the basal part), and boosts the OoC motion. In this paper, we use the *in vivo* experimental data on the OHC extracellular receptor potential together with the displacement of the OoC structural components to estimate energy exchange between the modes. It is found that when the OHC transmembrane potential leads the BM displacement by a phase between 0 and 180 degree, with an optimal value of 90 degree, the electrical power is transmitted into the BM mode. A phase difference between 180 and 360 gives rise to power dissipation on the BM. These phase ranges are shifted by 180 degree for the RL mode. Analyzing the experimental data reveals that the OHC active force dissipate power in the BM side while it amplifies the RL motion. Moreover, we utilize the BM/RL displacement amplitude to quantify the OHC active power generated by each hair cell.

10:00–10:15 Break

10:15

5aSA7. Investigation of low-frequency broadband dipole transducer driving by PMN-PT transverse shear mode. Yuyu Dai, Yinqiu Zhou, Xiuming Wang, Hongbin He, and Zhengbo Wang (Inst. of Acoust., Chinese Acad. of Sci., No. 21, Bei-Si-huan-Xi Rd., Beijing 100190, China, daiyuyu001@126.com)

A low-frequency broadband dipole transducer with a standard dipole directivity pattern is a crucial factor in the research and development of a sonic logging tool. A new dipole transducer design based on cylindrical shell oscillating is proposed in this paper, in which transverse shear polarization PMN-PT crystal stacks are used to provide a driving force to excite a cylindrical-shell oscillation to generate dipole acoustic field. The resonant frequency of the transducer is decided by the dimensions of crystal stacks. Piezoelectric coefficient d_{15} of the PMN-PT crystals can reached 7000 pC/N, which means there is enormous potential in high power transducer design; Several ceramic plates are connected in a series to reduce the resonant frequency of the exciting source and increase the driving amplitude at the same time so as to enhance the radiation power further; several stacks of different sizes are connected in a parallel to broaden the bandwidth. Finite element method is adopted to optimize the structure of transducer. According to the optimized results, a prototype is produced and then tested in anechoic tank. Test results show that the transmitting response is larger than traditional dipole transducer and the directivity pattern is better in the operating frequency range.

10:30

5aSA8. Fluid-structure interaction effects for minimizing transmission in waveguides: Time and frequency domain approach. Swaroop R. Vettamparambath and Abhijit Sarkar (Mech. Eng., IndianInst. of Technol. Madras, #445, Pampa Hostel, Chennai, Tamil Nadu 600036, India, swarooprajvr@gmail.com)

In many noise and vibration control applications, transmission loss in waveguides needs to be maximized. We propose a waveguide comprising of two different fluids with large impedance mismatch. The two dissimilar fluids are separated by two identical spring-mass combinations. An analytical model for such waveguide is undertaken using principles of one-dimensional linear wave propagation theory. Transmission loss for the waveguide across the frequency range is formulated in terms of (i) impedance mismatch of the fluids (ii) fluid-structure interaction parameter. It is shown that an appropriate choice of the above two parameters leads to a minimal transmission across the frequency range. The above inference is also corroborated through transient Finite Element Analysis. For transient simulation an initial condition is imposed on the system and the simulation is carried on till the first transmission is observed. The ratio of the maximum response in the transmitted pulse to the maximum response in the incident pulse is defined as the transmission ratio in time domain. It is observed that the transmission ratio computed in time domain correlate well with the transmission ratio formulated in the frequency domain.

10:45

5aSA9. Railway vibration and noise reduction using particle impact dampers. Wonseok Yang (Mech. Eng., Hanyang Univ., Hanyang Univ., Haengdang 1-dong, Seongdong-gu, Seoul, Korea, Seoul ASI|KR|KS013| Seoul, South Korea, wonseok_yang@naver.com), SangKeun Ahn (Mech. Convergence Eng., Hanyang Univ., Seoul, South Korea), Hyoin Koh (Korea RailRd. Res. Inst., Seoul, South Korea), and Junhong Park (Mech. Convergence Eng., Hanyang Univ., Seoul, South Korea)

Rolling noise is becoming a increasing concern for residential areas near railways. Rail vibration caused by moving loads of a train and corrugations generates noise. This study presented a particle impact dampers and its application to reduction of the rolling noise. The particle impact dampers to efficiently reduce the vibration were designed and verified using simplified models of a railway. To verify the particle impact damper performance, the vibration of a simplified railway attached with particle impact dampers was measured. The effects of different clearances and mass ratio of the damper to the railway was investigated. The numerical predictions of finite element model of impacting dampers were proposed and verified to the measured results to find the vibration reduction mechanism.

11:00

5aSA10. On frequency dependences of material damping and dynamic elastic properties. Tamás Pritz (Budapest Univ. of Technol. and Economics, Műegyetem rkp. 3-9, Budapest 1111, Hungary, tampri@eik.bme.hu)

The various solid materials may exhibit diverse damping and dynamic elastic behavior as a function of frequency over a wide range extending from zero hertz up to the meaningful high frequencies. Nevertheless, some general characters in the dynamic behavior of materials can be experienced, especially if a limited frequency range is concerned. The aim of this paper is to establish and classify the general characters of frequency dependence of linear damping and elastic properties with special emphasize to the sonic range and the materials used for sound and vibration control. Based on simple physical views, the frequency dependences of damping properties (loss modulus and loss factor) are established as a first step. It is shown that basically two types of damping behavior can be distinguished, namely, (a) damping increasing with frequency and (b) damping exhibiting a peak. All other types of damping (e.g., the decreasing and the hysteretic damping) can be interpreted through the above mentioned ones. The dynamic elastic properties (shear or bulk modulus, etc.) as a function of frequency are determined from the damping by considering causality principle. The frequency dependences predicted for the dynamic moduli are discussed.

11:15

5aSA11. Determining optimal equivalent source positions in wave superposition method by self-adaptive searching algorithm. Shaowei Wu and Yang Xiang (School of Energy and Power Eng., Wuhan Univ. of Technol., Peace Ave., Wuhan, Hubei Province, No. 1040, Wuhan, Hubei 430063, China, thinkwsw@qq.com)

The calculation accuracy of wave superposition method is influenced greatly by equivalent sources, their positions, and the frequency. What's more, nonuniqueness occurs at eigenfrequencies when monopole or dipole is used as the equivalent source. Although tripole can overcome the nonuniqueness, the computational overhead is very large due to its complex expression and the accuracy is still affected greatly by the positions. A method is proposed to reduce the calculation errors. In this method, monopole, which is the simplest source, is used as the equivalent source. The upper limit frequency for a radiator under a certain meshing pattern is predicted by using the fictitious pressure generated via a reference source. Then, the optimal equivalent source positions for each frequency corresponding to the actual vibration velocity boundary condition, in which the average rate of pressure change is minimal, are determined within the upper limit frequency by a searching algorithm. Numerical simulation results of a complex structure show that the calculation errors are significantly reduced. At last, the method is verified by an experiment for a cuboid radiator. Experimental results show that the proposed method is practicable and good at accuracy.

11:30

5aSA12. Sound characteristic analysis of Multi-layer sound- absorbing materials using impedance tube. Hyungwoo Park (SoongSil Univ., 1212 Hyungham Eng. Building 369 Snagdo-Ro, Dongjak-Gu, Seoul, Seoul 156743, South Korea, pphw@ssu.ac.kr), Seonggeon Bae (Daelim Univ., Seoul, South Korea), Myungjin Bae (SoongSil Univ., Seoul, South Korea), and Duckhee Lee (Korea RailRd. Res. Inst., Gyeonggi-do, South Korea)

With the development of the field of transportation, vehicles have come to be driven fast. As a result, due to their high speed, railways are the cause of increased noise inside the railway vehicle. Methods for reducing noise present themselves in various ways. However, it is difficult for a method to be effective without a costly and difficult implementation of technology. In general, to improve the characteristics of vehicle interior noise conditions, which can increases the effect of sound absorbing or insulation materials, it is necessary that any sound absorbing material be located between the outer and inner walls of the vehicle. In this paper, we perform an experiment on the acoustic characteristics of a composite multilayer type sound-absorbing material that can be used to reduce the interior noise of a vehicle. In our tests, we used an impedance tube, which can scan a plane wave with a speaker for the test-material. The tube is fabricated in a circular symmetrical shape. This overall method can be used to evaluate acoustic transmission loss. The results found in this study can be used to show that the selection of a multi-layer sound-absorbing material can allow users to achieve the characteristics of noise reduction. With the results delineated in this study, a multi-layer high density material can be confirmed to show improved performance this material can also be used to check the characteristics of the frequency response of the shape of the surfaces.

FRIDAY MORNING, 6 NOVEMBER 2015 GRAND BALLROOM 8, 8:30 A.M. TO 10:00 A.M.

Session 5aSCa

Speech Communication: Intonation, Tone, and Prosody (Poster Session)

Tessa Bent, Chair
Department of Speech and Hearing Sciences, Indiana University, 200 S. Jordan Ave., Bloomington, IN 47405

Authors will be at their posters from 8:30 a.m. to 10:00 a.m. To allow authors an opportunity to see other posters in their session, all posters will be on display from 8:30 a.m. to 12:00 noon.

Contributed Papers

5aSCa1. Two strategies for distinguishing ngã and sắc tones in Northern Vietnamese. Taylor L. Miller, Angeliki Athanasopoulou, Nadya Pincus, and Irene Vogel (Linguist & Cognit. Sci., Univ. of Delaware, 125 E Main St., Newark, DE 19716, tlmiller@udel.edu)

The six tones of Northern Vietnamese involve F0 and phonation properties. We examine the acoustic manifestation of two rising tones usually characterized as having distinct phonation (ngã = creaky and sắc = modal) in 1584 vowels produced by 9 Hanoi speakers (88 real three word compounds, 8 target vowels /a/, /i/, /u/ with sắc and ngã in first two syllables). Based on measurements of F0, energy, duration, and phonation properties (spectral tilt, CPP, and HNR), we observed two strategies for producing the two tones: (a) both F0 and phonation differences, where creaky voice appeared in >78% of the ngã tones (N = 7); (b) only F0 difference, where creaky voice appeared in <6% of the ngã tones (N = 2). Classification of the data into the two tones with Binary Logistic Regression Analyses confirmed the distinct behaviors. In the first strategy, the main property distinguishing ngã from sắc is HNR (84%), but F0 was also very successful (75%). In the second strategy, F0 was the only significant property (90%). Given that there were no age, gender, or educational differences, we suggest that the patterns may be due to (i) a regional dialectal difference or (ii) a change in progress in Vietnamese.

5aSCa2. Perception and production abilities of question vs. statement intonation patterns in young deaf children with early cochlear implantation. Sangsook Choi, Ioana Barbu, Cynthia Core, and James Mahshie (Speech and Hearing Sci., The George Washington Univ., 2115 G St. NW, Washington, DC 20052, sangsook_choi@email.gwu.edu)

Little research exists studying production and perception of prosody in early-implanted children with cochlear implants (CIs). Because of limited F0 information conveyed by CIs, there is particular interest in the impact of CIs on intonation perception and production. The aim of the present study was to describe and compare the ability of hearing (HC) and implanted (IC) children to perceive and produce distinctions between question vs. statement intonation patterns. Nine HC and 9 IC between 38 and 58 months of age participated in the study. All IC received their first implant prior to 15 months and had no other identified medical or developmental problems

besides hearing loss. To determine the children's ability to perceive rising and falling intonation, an imitation task was used. Results showed no significant difference in perception between the groups ($p = .09$). Intonation production was examined by eliciting yes–no questions and statements during a play-based task. Production measures included mean, range, and slope of F0. While F0 range was significantly greater for IC than for HC ($p = .015$), no other measure was found to be significantly different between the two groups. Overall, early-implanted deaf children with CIs appear to develop intonation comparable to their hearing peers.

5aSCa3. Speech variability and prosody in childhood apraxia of speech. Toby Macrae, Kaitlin Lansford, and Emily Berteau (Commun. Sci. and Disord., Florida State Univ., 201 W. Bloxham St., Tallahassee, FL 32306-1200, tmacrae@fsu.edu)

This is a follow-up to a paper that was presented at the 2014 Convention of the American Speech-Language-Hearing Association, which included preliminary data from 12 children. Data collection is ongoing and the data from all participants will be presented at the Acoustical Society of America Meeting in 2015. While speech variability and disordered prosody are core features of childhood apraxia of speech (CAS), much of the research in this area is descriptive and/or subjective. The purpose of the proposed study is to compare children with CAS to children with non-CAS speech sound disorders (SSDs) using more objective acoustic measures of variability and prosody, including: (1) durational variability of the phrase "Buy Bobby a puppy," (2) durational variability of /ɑ/ in "Bobby," (3) durational variability of /ʌ/ in "puppy," (4) durational variability of voice onset time for /p/ in "puppy," (5) spectral variability of the first and second formants (F1 and F2) for /ɑ/ in "Bobby," (6) spectral variability of F1 and F2 for /ʌ/ in "puppy," and (7) three stress metrics from Liss *et al*. (2009), which relate variability in consonant durations to variability in vowel durations and have been shown to differentiate between speakers with and without dysarthria and among different dysarthria subtypes. Preliminary data were encouraging. Children with CAS showed relatively more variability in consonant durations than vowel durations. Children with non-CAS SSDs showed relatively more variability in vowel durations than consonant durations.

5aSCa4. The intonation of wh-in situ questions in Northern Peninsular Spanish. Carolina Gonzalez and Lara Reglero (Modern Lang. and Linguist, Florida State Univ., 625 University Way, DIF 322, Tallahassee, FL 32306-1540, cgonzalez3@fsu.edu)

This project investigates the intonational characteristics of wh-in situ questions (As in: ¿Compraste qué? *'You bought what?'*) in Northern Peninsular Spanish. Although these questions reportedly occur with various pragmatic readings in several Spanish dialects (Uribe-Etxebarria 2002; Chernova 2013; Reglero and Ticio 2013), their intonation remains to be investigated. Data from 22 speakers from Northern Peninsular Spanish was collected in a reading and an elicitation task. Each task included 30 contextualized wh-in situ questions representing information-seeking, echo-repetition, and echo-surprise readings. Target sentences were interspersed among declaratives and yes–no questions. Preliminary results from the elicitation task are discussed for two female participants. Prevalent pitch contours are analyzed following Spanish ToBi conventions (Face and Prieto 2007). In addition, we report the global tonal range for each type of wh-in situ, as well as the tonal range average from the nuclear tone to the boundary tone. It is expected that surprise contexts will have the greatest tonal range, followed by echo-repetition contexts. Finally, we explore the prevalence of intermediate phrases prior to the final wh-word for the three contexts, which might have repercussions for the syntactic analysis of wh-in situ in Spanish (Uribe-Etxebarria 2002 vs. Reglero and Ticio 2013).

5aSCa5. The intonation of declaratives and absolute interrogatives in Valencian Spanish. Jessica Craft (Spanish, Florida State Univ., 625 University Way, DIF356, Tallahassee, FL 32306, jmc07f@my.fsu.edu)

This study presents data on the intonation of broad focus declarative sentences and information-seeking absolute interrogative sentences in Valencian Spanish, as the characteristics of this dialect have not previously been described. The main research questions of this study are what types of intonation patterns are typical for Spanish in this region and in what ways these patterns are similar and/or different from the ones attested for Castilian Spanish and Valencian Catalan. The speech data analyzed came from six native speakers of Valencian Spanish, all early bilinguals of Valencian Catalan. A total of 240 sentences were analyzed in Praat (Boersma and Weenink 2014) following standard Sp_{ToBI} and Cat_{ToBI} conventions (Beckman, *et al*. 2002; Estebas-Vilaplana and Prieto 2010; Prieto 2014). The study focuses on the pitch accents used in the prenuclear and nuclear positions, as well as the boundary tones for both sentence types. The speech data show use of intonational contours from both Valencian Catalan and Castilian Spanish and demonstrates the profound influence of Catalan in the Spanish of this region. Furthermore, the data are consistent with what has been reported for other Spanish-Catalan bilingual speakers in other regions of Spain (Romera and Elordieta 2013, Simonet 2011, Romera, *et al*. 2008).

5aSCa6. Production of emotional intonation among Mandarin and English speakers. Ratree Wayland, Yiqing Zhu, and Michelle Perdomo (Linguist, Univ. of Florida, 2801 SW 81st St., Gainesville, FL 32608, ratree@ufl.edu)

Some researchers claim that intonation can be used to express specific emotion while others argue against the existence of emotion specific intonation patterns. In addition, languages differ in their use of intonation pattern to deliver similar emotion, and that L2 learners have the tendency to use L1 knowledge to produce intonation. Previous research shows that a falling successive addition boundary tone was used to express "disgust" or "anger" while a rising successive addition tone was used to convey "surprise" and "happy" emotions in Mandarin. In this study, we compare intonation patterns used to express five emotions: anger, disgust, surprise, joy, and neutral by 10 Mandarin and 10 English speakers in 1, 2, or 5-word utterances in English. Mandarin speakers were also asked to produce all 5 emotions in 1, 2 and 5-word utterances in Mandarin. Preliminary analyses from one Mandarin speaker showed that mean F0 of utterances produced with different emotions are significantly different in all three utterance lengths in both Mandarin and English. Inconsistent with previous research, a "falling" successive addition tone is used in all five emotions in Mandarin and in four emotions, except disgust, in English.

5aSCa7. L + H* and H* pitch accents in Mandarin Chinese. Yiqing Zhu and Ratree Wayland (Linguist, Univ. of Florida, 2801 SW 81st St., Gainesville, FL 32608, ratree@ufl.edu)

In this study, we examine acoustic correlates of L + H* and H* pitch accents in Mandarin Chinese. In English, L + H* denotes "exclusiveness" and H* conveys "new" information. For example, L + H* A. Katie did not pet the cat, (Kellie did). H* B. Katie did not pet the cat (she pet the dog). Ten Mandarin speakers were asked to produce the English equivalent L + H* and H* pitch accents in Mandarin as in C and D: L + H* C. 咪妮 没有 摸 猫, 妞蒙 摸 了 猫 MiNi meiyou mo mao, NiuMeng mo le mao. *MiNi did not pet the cat, it is NiuMeng who petted the cat*. H* D. 咪妮 没有 摸 猫, 咪妮也 没有 摸 狗 MiNi meiyou mo mao, MiNi ye meiyou mo gou. *MiNi did not pet the cat, and she did not pet the dog either*. MiNi and NiuMeng were produced with all combinations of four Mandarin tones. Preliminary findings from one speaker suggest an interaction between tones and pitch accents such that pitch contour and pitch height of both types of pitch accents vary as a function of tones.

5aSCa8. Durational characteristics of sentence-medial and sentence-final pauses in the production of a paragraph. Kuniko Kakita (Liberal Arts and Sci., Toyama Prefectural Univ., 5180 Kurokawa, Imizu, Toyama 939-0398, Japan, kakita@m3.spacelan.ne.jp) and Shizuo Hiki (Faculty of Human Sci., Waseda Univ., Tokorozawa, Japan)

The present study investigated the durational characteristics of sentence-medial and sentence-final pauses in the production of a paragraph, with an aim to elucidate the factors that determine the durational organization of connected speech. A phonetically trained native speaker of Japanese read a paragraph consisting of eight sentences at a moderate speaking rate. Three recordings varying slightly in total duration — roughly 55 s, 52 s (−5%), and 49s (−10%) — were analyzed acoustically. Results showed that

approximately 30% of the paragraph duration was pause duration, of which about 80% was sentence-final and 20% sentence-medial. Pause duration affected paragraph duration more significantly than speech duration, e.g., 10% shortening in paragraph duration resulted from 25% shortening in pause duration but only 5% shortening in speech duration. The duration of sentence-medial pauses was positively correlated to the duration of preceding speech, while the duration of sentence-final pauses reflected the internal structure of the paragraph, i.e., paragraph-internal topic transitions were accompanied by longer pauses, possibly providing opportunities, too, for physiological adjustments such as breathing and swallowing. The ratio of accumulated pause duration to accumulated speech duration increased in an asymptotic manner, approaching the final ratio value near the end of paragraph production.

FRIDAY MORNING, 6 NOVEMBER 2015 GRAND BALLROOM 8, 10:30 A.M. TO 12:00 NOON

Session 5aSCb

Speech Communication: Foreign Accent and Multilingual Speech Production and Perception (Poster Session)

Rajka Smiljanic, Chair
Linguistics, University of Texas at Austin, Calhoun Hall 407, 1 University Station B5100, Austin, TX 78712-0198

Authors will be at their posters from 10:30 a.m. to 12:00 noon. To allow authors an opportunity to see other posters in their session, all posters will be on display from 8:30 a.m. to 12:00 noon.

Contributed Papers

5aSCb1. Acoustic detail in monolingual and bilingual children's representations of English and Spanish. Cynthia P. Blanco, Rajka Smiljanic (Univ. of Texas at Austin, 305 E. 23rd St., Linguist, B5100, Austin, TX 78712, cindyblanco@utexas.edu), and Colin Bannard (Univ. of Liverpool, Liverpool, United Kingdom)

Children must learn to process variations in the pronunciation of their language(s), but they must also learn the social meaning of particular kinds of variation. By preschool, children's initially overly specific lexical representations have generalized to reflect commonalities in pronunciations, thus allowing children to recognize accented productions as instances of familiar lexical items (Best *et al*., 2009; Schmale, *et al*., 2010, 2011, 2012; Stager and Werker, 1997). However, elementary-school-aged children struggle to use the phonetic variation present in accented speech to understand social differences among talkers (Floccia *et al*., 2009; Girard *et al*., 2008). In the present study, we investigated children's ability to associate acoustic cues with a particular language as a function of their language background (monolingual, significant L2 exposure, or bilingual). Children decided whether nonce words containing language-specific sounds were produced by a Spanish speaker or an English speaker. Language-specific cues included phonemes unique to Spanish (/r/) or English (/ɹ, θ/), or sound categories common to both languages but produced differently in each (/ɪ, u/). The categorization patterns and reaction times of the three groups were compared, and results indicate that children with exposure to or proficiency in Spanish categorized the nonce words more accurately than monolinguals.

5aSCb2. Phonetic divergence in bilingual speakers is modulated by language attitude. Wai Ling Law (Linguist, Purdue Univ., Beering Hall of Liberal Arts and Education, 100 North University St., West Lafayette, IN 47907, wlaw@purdue.edu) and Alexander L. Francis (Speech, Lang. & Hearing Sci., Purdue Univ., West Lafayette, IN)

Bilingual speakers' speech varies phonetically according to many factors such as age of arrival and of acquisition of the second language (L2) (e.g., Flege *et al*., 1999). However, such temporal factors may not be as relevant to populations with more uniform language experience, as in pervasively multilingual societies. In such diglossic situations, speakers' attitudes toward each of their languages may have a stronger influence on everyday pronunciation, as they do for language learning (Moyer, 2007) and phonetic accommodation to interlocutors (Dmitrieva *et al*., 2015). This study was designed to determine whether bilingual speakers' attitude toward their language(s) and associated culture(s) modulates phonetic properties of their speech. Native Cantonese-English bilinguals living in Hong Kong ($N = 20$) produced near homophones in both languages under conditions emphasizing each language on different days. The degree of diphthongization of Cantonese /o/ and English /oʊ/, and Cantonese /aɪ/ and English /ɑɪ/ were quantified acoustically and compared to attitude scores elicited in a questionnaire. Participants with a more positive attitude toward Cantonese showed larger cross-language differences in diphthongization of these pairs, demonstrating an effect of language attitude on phonetic properties of speech and highlighting the contribution of sociolinguistic factors to phonetic variability in diglossic contexts.

5aSCb3. How do L1 and L2 influence on the acquisition of L3 (English) stress pattern. Mahire Yakup and Dina Omanova (World Lang. and Lit., Nazarbayev Univ., Block 38-1104, 53 Kabanbay Batyr Ave., Astana, Aqmola 010000, Kazakhstan, yakefu.mayila@nu.edu.kz)

In this research, we investigated the acquisition of English stress by trilingual speakers (Kazakh/Russian (L1)-Russian/Kazakh (L2)-English (L3). Stress in Kazakh, as a Turkic language, is on the final position (Johnson, 1998) and was cued by fundamental frequency (Kirghner, cited from Kondibaeva, 2010). However, in Russian, stress was cued by duration and intensity (Hamilton, 1980; Kuznetsova, 2006). In this research, we used two different trilingual groups in which the Kazakh-Russian-English trilingual group has Kazakh as a dominant language and first language; on the other hand, the Russian-Kazakh-English trilingual group has Russian as a dominant language with the advanced level of Kazakh. However, both groups have high level of English (IELTS = 6.5 and above). All participants from both groups produced the noun-verb stress pattern words in sentences. In the production of ten female speakers from each group, average fundamental frequency, duration, average intensity, and first and second formant frequencies for vowels were collected in the stressed and unstressed syllables. The result showed that for Russian-Kazakh-English speakers, duration and

intensity are stronger cues than F0. Kazakh-Russian-English trilinguals used all parameters, but duration was strongly associated with final lengthening. The results will be discussed in terms of L1/L2 transfer into the acquisition of L3.

5aSCb4. Accent and fluency in third language acquisition. Hiromi Onishi (Grinnell College, 1210 Park St., Grinnell, IA 50112, honishi84@gmail.com)

This paper examined the influence of L2 on L3 accent and fluency. Target participants were native speakers of Chinese who have studied English as an L2 prior to beginning their study of Japanese as L3. Participants were recorded in L2 and L3, and their speech samples were rated by expert judges of respective language. The judges were asked to rate each speaker based on foreign accentedness and overall fluency. The results from English and Japanese were analyzed using correlation analysis. The result of the correlation analysis showed a positive correlation between accent in L2 and L3, which suggests that, regarding foreign accentedness, the better a speaker performs in L2, the better they also perform in L3. The correlation between L2 and L3 in terms of fluency did not reach significance, mostly due to the fact that fluency rating in English was done mildly by the judges. The result nevertheless showed a clear trend toward positive correlation between the two languages. This study contributes to the area of Third Language Acquisition by supporting the idea that L3 acquisition is qualitatively different from L2 acquisition, and phonological acquisition in L3 is influenced not only by the learner's L1 but also their L2.

5aSCb5. Foreign accentedness of English sentences spoken by Japanese EFL learners and Japanese teachers of English: A first report. Natsumi Maeda (DaitoBunka Univ., 1-9-1, Takashimadaira, Itabashi, Tokyo 175-8571, Japan, h20625maeda@hotmail.co.jp) and Kiyoko Yoneyama (DaitoBunka Univ., Itabashi-ku, Tokyo, Japan)

This study reports the results of a foreign-accented-rating experiment that investigate the foreign accentedness of spoken English sentences by two Japanese groups, Japanese EFL learners and Japanese teachers of English. This study aims first to investigate whether spoken English sentences by Japanese teachers of English are judged less foreign-accented than those by Japanese EFL learners, and second to investigate whether American-English listeners rate spoken English sentences by Japanese speakers more severely than Japanese listeners do. The stimuli were five sentences adopted from Flege, Munro, and McKay (1995) spoken by 33 Japanese EFL learners and 33 Japanese teachers of English. Ten American-English speakers and ten Japanese speakers were asked to rate the stimuli presented visually and auditorily by clicking along a line on the computer screen for their ratings. The participants' original responses were converted to 10 scales and were submitted to the analyses. The results showed that spoken English sentences by Japanese teachers of English were rated significantly less Japanese-accented than those by Japanese EFL learners. The results further revealed that as in the previous studies, the American-English speakers rated spoken English sentences by two Japanese groups significantly more severely than Japanese speakers. [Work supported by JSPS.]

5aSCb6. Non-word repetition task by young Japanese learners of English. Hiromi Kawai (Ctr. for Teaching English to Children, Kanda Univ. of Int.. Studies, 1-4-1 Wakaba, Mihama-ku, Chiba City 2610014, Japan, kawai-h@kanda.kuis.ac.jp)

This study identified the L2 sound processing problems of young Japanese EFL learners on articulatory production ability of English sounds, without intervention of lexical representation. A non-word repetition test was conducted based on the L1 English children's speech processing system as proposed by Stackhouse and Wells (1997). 203 5th and 6th graders from a public elementary school in Tokyo participated in this study. Nine L1 English normally developing children participated in the test as a reference group. During the non-word repetition test, the participant children watched a native speaker of American Standard English on a computer monitor pronouncing 15 non-words ranging in length from one to three syllables and repeated each non-word following the NS model pronunciation. The recorded performances of the participants were judged by two experts in phonetics and phonology and a native speaker of English specializing in university-TESOL. There was no significant difference between the three judges in perceptual rating ($p > .05$). An ANOVA showed a significant difference between the Japanese children and the L1 English children in the total score of the repetition test. The difficulty of the item analysis, however, revealed a tendency in both Japanese and L1 English children in articulating each syllable.

5aSCb7. Listeners pay attention to rhythmic cues when judging the nativeness of speech. Elisa Pellegrino (Dept. of Literary, Linguist and Comparative Studies, Univ. of Naples L'Orientale, via Duomo 219, Naples 80138, Italy, pellegrino.elisa.1981@gmail.com) and Volker Dellwo (Univ. of Zuerich, Zurich, Switzerland)

Native listeners are good at detecting whether speech is foreign-accented or not. Here, we tested the role of rhythmic cues from the amplitude envelope (ENV) in this process. In a binary forced-choice perception experiment, ten L1 Italian listeners listened to 32 stimuli, each containing two Italian utterances of identical lexical content under the following conditions: (a) Both utterances were produced by a non-native speaker and were manipulated with either the ENV of a native German speaker of Italian and Italian L1 speaker (at 10 and 30 frequency bands). (b) One utterance was produced by an L1 Italian, the other by an L2 speaker. For 10 and 30 frequency bands their ENVs were exchanged (speech chimeras). Listeners' task was to choose which of the utterances in a stimulus was the more native-like. In condition (a), listeners' probability to choose the utterance with the L1 envelope was above chance at 10 bands (0.72) and increased with 30 bands (0.78). In condition (b) listeners' probability to choose the utterance with the L1 ENV was 0.19 at 10 bands and 0.46 at 30 bands. We conclude that rhythmic cues in the speech ENV influence listeners' perception of nativeness.

5aSCb8. Disentangling the contribution of pitch and duration cues in first and second language perception of the Mandarin neutral tone. Arthur L. Thompson and Francis Nolan (Dept. of Theor. and Appl. Linguist, Univ. of Cambridge, Sidgwick Ave., Cambridge CB3 9DA, United Kingdom, alt54@cam.ac.uk)

Most L1 and L2 Standard Mandarin (SM) perception tests focus on the four lexical tones. However, none take into account the neutral tone (NT) for L2 speakers, and few do for L1 speakers (e.g., Yang, 2010). Pitch onset aside, the relatively short duration of NT syllables is assumed to be their primary perceptual cue (Lin and Yan, 1980). This study tested which perceptual cues are used by L1 and L2 groups. To this end, 9 L1 and 9 L2 learners (L1 British English) participated in a five-way alternative forced-choice tone identification task. Three minimal pair disyllabic tokens containing NT were used as stimuli. Syllables carrying NT were manipulated in PRAAT using steps of 30, 50, 70, and 100% manipulation for pitch and/or duration. Pitch was progressively manipulated to mimic that of a lexical tone, while duration progressively approached that of a lexical tone in second syllable position. This study found that L2s rely primarily on duration to identify NT, while L1s rely primarily on pitch. This expands previous studies showing that duration interferes with L2 SM tone perception (Blicher *et al*., 1991; Chang, 2011). By contextualizing this finding, new models are proposed for L2 SM tone perception and acquisition.

5aSCb9. Production and perception skill developments of Korean coronal obstruents by inexperienced English-speaking learners of Korean. Hanyong Park (Dept. of Linguist, Univ. of Wisconsin-Milwaukee, P.O. Box 413, Milwaukee, WI 53211, park27@uwm.edu)

The present study investigates how speech production and perception abilities develop in second language learning among learners in a classroom setting. English-speaking students taking a first semester college course in Korean participated in both production and perception tasks. In the production task, the participants read a list of Korean frame sentences with target stimuli consisting of Korean /t t' t^h s s'/ with /a/ in CV and VCV. To assess the production accuracy, native Koreans identified the consonants from the learners' productions. In the perception task, the participants listened to the same corpus of Korean stimuli and identified the consonants with Korean

orthography. The data were collected four times over two semesters: Week 5 or 6, and Week 13 or 14 of each semester. Results indicate that the learners' overall production and perception abilities are correlated to each other in some but not all data collection times. Further analyses show that over two semesters, most learners did not improve much in overall perception abilities. Not much learning occurred either in production or perception for some sounds (e.g., /s/, /s'/). These findings suggest different learning units for production and perception as well as the powerful influence of native language.

5aSCb10. Speaking rate variability in spontaneous productions by non-native speakers. Tuuli Morrill (Linguist, George Mason Univ., 4400 University Dr., 3E4, Fairfax, VA 22030, tmorrill@gmu.edu) and Melissa Baese-Berk (Linguist, Univ. of Oregon, Eugene, OR)

Most research examining differences between native and non-native speech measures mean differences at the segmental level. Some work has examined non-segmental characteristics of speech such as speaking rate; however, this work has also typically examined only mean differences. In the present study, we ask whether within-speaker variability, in addition to mean differences, characterizes differences between non-native and native speech. Specifically, we examine speaking rate in spontaneous productions by both native and non-native speakers of English. Preliminary work suggests that rate change across utterances in read productions of non-native speech is more variable than in read productions of native speech (Baese-Berk and Morrill, 2014, *Indianapolis ASA*). However, it is possible that read speech contains sources of variability that are specific to processing difficulties during reading. In the present study, we examine native speakers of Korean and Mandarin producing spontaneous speech in English and compare their speech to both native speakers of English, and read productions by these same non-native speakers. We measure mean speaking rate within utterances, as well as the amount of rate change (slowing or speeding up of speaking rate) from utterance to utterance. Results will contribute to an understanding of the role of variability in non-native speech production.

5aSCb11. Effects of training methods and attention on the identification and discrimination of American English coda nasals by native Japanese listeners. Takeshi Nozawa (Lang. Education Ctr., Ritsumeikan Univ., 1-1-1 Nojihigashi, Kusatsu 525-8577, Japan, t-nozawa@ec.ritsumei.ac.jp)

The accuracy with which native Japanese listeners identified and discriminated American English coda nasals in /CVN/ context was assessed before and after training. The listeners were divided into four groups, each of which received a different type of training. Two of the four groups were vowel-oriented; one of these groups received vowel identification training (VI), while the other received vowel discrimination training (VD). The other two groups were nasal-oriented. One of the nasal-oriented groups received nasal identification training (NI), and the other received nasal discrimination training (ND). The results revealed that the two nasal-oriented groups made more gains in its ability to identify and discriminate American English coda nasals than the vowel-oriented groups after training. The result implies that identification and discrimination trainings are equally effective in improving listeners' sensitivity to identify and discriminate American English coda nasals. The two vowel-oriented groups achieved modest improvement in identification and discrimination accuracy, which suggests that repeated exposure to stimuli can enhance listeners' sensitivity even when their attention is not on the target segment.

5aSCb12. One of these accents sounds like the other; one of these accents is not the same. Rachel M. Miller (Psych., California State Univ. San Marcos, 333 S. Twin Oaks Valley Rd., San Marcos, CA 92078, rmiller@csusm.edu)

Accented speech occurs when the structure of a talker's native language causes deviations from the speech productions norms of the non-native language being produced (e.g., Spanish-accented English; Tarone, 1987). The current study tested sensitivity to deviations shared across accents by asking two groups of listeners to judge similarities and differences between Spanish- and Chinese-accented speech samples. The matching group was asked to judge whether a model's accented token (e.g., Spanish) was more similar in accent to a token in the same (e.g., Spanish) vs. a different accent (e.g., Chinese). The discrimination group was asked to judge whether a model's accented token (e.g., Spanish) was different in accent from a token in the same (e.g., Spanish) vs. a different accent (e.g., Chinese). Results showed that listeners are able to make similarity matches at significantly greater than chance (50%) levels, suggesting that they are perceptually sensitive to the similarities between non-native accents. However, listeners were not good at picking out the "dissimilar" accent. This experiment shows a discrepancy in listeners' ability to compare accents based on whether they focus their judgments on similarities or differences between the accents, suggesting that different cognitive processes may be used in matching versus discrimination type tasks.

5aSCb13. The effect of informational and energetic masking on foreign-accent adaptation. Elisa Ferracane, Cynthia P. Blanco, Michelle Dubois, Andrea Manrique, and Rajka Smiljanic (Linguist, Univ. of Texas, 305 E. 23rd St., Austin, TX 78712, elisa@ferracane.com)

Speech understanding in noisy environments can be compromised through energetic (EM) and informational (IM) masking. EM reduces intelligibility of target speech through spectro-temporal overlap with the masker at the auditory periphery level. IM refers to the higher-level interference, such as competing attention, linguistic interference, and increased cognitive load. The present study examined the effects of EM and IM on foreign-accent adaptation. Native English listeners heard blocks of sentences produced by native-accented (NA) or foreign-accented (FA) talkers (Korean, Spanish) mixed with speech-shaped noise (SSN) or two-talker, native-accented babble and responded to a visual probe. Preliminary results show that listeners were more accurate and faster in babble compared to SSN. The more successful FA adaptation in the babble condition may be related to the presence of dips in the masker energy or the ability of listeners to successfully separate FA target from the NA background speech. Additionally, the acoustic properties of the target sentences, such as speaking rate and pausing, are examined to understand their effect on FA adaptation in each of the two noise conditions. These findings suggest that IM was less disruptive than EM for FA adaptation even though listeners were processing FA speech with an increased cognitive load.

5aSCb14. The effect of background speech variation on perceived foreign accent. Dylan Pearson (Linguist, Univ. of Wisconsin-Milwaukee, 3243 N Downer Ave., Milwaukee, WI 53211, dvp@uwm.edu), Amara Sankhagowit (Linguist, Univ. of Chicago, Milwaukee, WI), and Hanyong Park (Linguist, Univ. of Wisconsin-Milwaukee, Milwaukee, WI)

We investigate what effect the presence of differing degrees of accented babble speech has on the perceived foreign accent of the target utterances. We presented various degrees of foreign accented English sentences in multi-talker babble conditions to native speakers of English to rate the accentedness on a 1−9 Likert scale. Male and female native speakers of English and native Korean speakers having light to heavy foreign accent produced the target stimuli. We overlapped babble recorded from two talkers (1 male and 1 female) to generate the multi-talker babbles, where the talkers were speaking in native English, native Korean, heavy accented English, and light accented English. Our results show a tendency for listeners to rate the stimuli presented in more native-rated babble as sounding more native-like than the same utterance presented with less native babble. The data also points to native target speech being more sensitive to a change in the degree of accent in babble than non-native target speech. All taken together, the results suggest a "bleedthrough effect" as a result of pieces of the background babble appearing to be processed along with the target speech, thus affecting the perceived accent.

Session 5aUW

Underwater Acoustics: Communications, Transducers, Target Response, and Nonlinear Acoustics

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Contributed Papers

8:00

5aUW1. A single equation for predicting required ocean and seismic acoustic fiber optic sensor response. Fred C. DeMetz (Sound Path Technologies, LLC, 9056 Camellia Ct, Ste. 100, Rancho Cucamonga, CA 91737, fred@soundpathtech.com)

In the past decade, requirements have evolved for systems of ocean bottom and seismic downhole acoustic sensors with high dynamic range, wider bandwidths, and which will operate reliably for a decade or more in high-pressure-high-temperature environments. As seismic and acoustic survey spatial resolution, operating depth, and range requirements have increased, higher sensor string counts have been required to provide the needed improvements in target definition. Fiber optic sensors and telemetry systems are being developed which allow HPHT operation, without vulnerable electrical telemetry in the "wet" end of the system, and which can reliably transmit high-sensor count string outputs which are 10's of km from the processor. This paper introduces a modified version of the SONAR equation which allows straight forward estimation of the required fiber optic acoustic sensor response, early in the system design stage, and allows the system engineer to define and optimize sensor response requirements and help minimize system performance risks.

8:15

5aUW2. Wireless underwater acoustic beamforming using chip-scale atomic clock timers. Simon E. Freeman (Underwater Acoust., Naval Res. Lab., 6819 Duke Dr., Alexandria, VA 22307, simon.freeman@gmail.com), Lloyd Emokpae, and Geoffrey F. Edelmann (Underwater Acoust., Naval Res. Lab., Washington, DC)

Obtaining the directionality of the sound field is typically performed using a cabled array of hydrophones, connected to a central data collection device. The cable introduces vulnerability wherein an electrical break in the line or dragging by currents or anchors may render the array inoperable. An underwater wireless beamforming system, which transmits time and recorded low-frequency sounds using directional high-frequency acoustic communications between elements, is presented here. Each element is contained in a standalone housing that contains batteries, amplifiers, signal conditioning hardware and a field-programmable gate array (FPGA)-based signal processing computer. Low-frequency sounds are recorded at a sampling rate of 2 kHz, then transmitted using binary phase-shift-key (BPSK) encoding at a center frequency of 750 kHz. Inter-element spacing estimates are facilitated by the time-stamped high-frequency signals. System timing is controlled by a Symmetricom® SA.45s chip-scale atomic clock (CSAC) embedded in each unit, connected to the FPGA. In addition, a CSAC output waveform is divided and modified to form the high-frequency multiplier waveform for the BPSK signal. The elements were deployed in shallow water offshore of Panama City, FL, in August 2015. [This work was supported by the Office of Naval Research.]

8:30

5aUW3. Improved multiple focusing with adaptive time-reversal mirror in the ocean. Gi Hoon Byun and Jea Soo Kim (Ocean Eng., Korea Maritime and Ocean Univ., Korea Maritime Univ., Dongsam 2-dong, Yeongdo-gu, Busan 606-791, South Korea, gihoonbyun77@gmail.com)

The linearly constrained minimum variance (LCMV) method in adaptive signal processing is designed in such a way that it attempts to minimize the output power subject to constraints on the look directions. This adaptive method has been applied to time-reversal mirror (TRM) for simultaneous multiple focusing and its efficiency has been verified by [Kim*et al*., J. Acoust. Soc. Am. **109** (5), 1817–1825 (2001)]. However, the norm of the weighting vector $\|\mathbf{w}\|$ that satisfies the constraints tends to become very large when two probe sources (PS) are close to each other. It causes prominent spatial sidelobes as the weighting vector $\mathbf{w}$ is back-propagated in TR focusing. In this study, a relationship between $\|\mathbf{w}\|$ and PS locations is illustrated, and LCMV method is partially reformulated to calculate the weighting vector $\mathbf{w}$ which satisfies new constraint responses, so that sidelobes are significantly suppressed. The proposed method for improved adaptive time-reversal mirror for stable simultaneous multiple focusing is verified using numerical simulations and experimental data.

8:45

5aUW4. Focal properties of an underwater acoustic Fresnel zone plate lens. David C. Calvo, Michael Nicholas, Abel L. Thangawng, and Christopher N. Layman (Acoust. Div., Naval Res. Lab., 4555 Overlook Ave., SW, Washington, DC 20375, david.calvo@nrl.navy.mil)

Fresnel zone plate (FZP) lenses provide thin alternatives to conventionally sized acoustic lenses. We present experimental characterization of an underwater acoustic FZP lens fabricated at the Naval Research Laboratory. This diffractive lens has a short focal length (numerical aperture angle of $=62°$) which provides a narrow focal spot with a diffraction limited first-null radius $0.61\lambda/\sin$. The 13 in diameter FZP consists of opaque rubber foam rings attached to a thin PDMS rubber substrate. Ultrasonic measurements of transmission were made using a scanning needle hydrophone and a 200 kHz piston source. Measured focal gain varied between 20 and 15 dB for incidence angles between 0 and 12°, respectively. These gains agreed with predictions computed using a wide-angle beam propagation method. Measured transverse focal shift agreed with geometrical constructions used in conventional lens theory. Axisymmetric finite-element computations using Fourier decomposition of the oblique incident field are also presented which provide a more accurate treatment of scattering from the penetrable rubber foam. These simulations resolve high-order, very narrow focusing in regions close to the lens (~5 wavelengths). A comparison of spherical and coma aberration between a conventional and FZP lens are also reported. [Work sponsored by the Office of Naval Research.]

9:00

5aUW5. High frequency p-wave attenuation dispersion in water-saturated granular medium with bimodal grain size distribution. Haesang Yang (Underwater Acoust. Lab., Dept. of Naval Archi. & Ocean Eng., Seoul National Univ., 1, Gwanak-ro, Gwanak-gu, Seoul 151-744, South Korea, coupon3@snu.ac.kr), Keunhwa Lee (Sejong Univ., Seoul, South Korea), and Woojae Seong (Seoul National Univ., Seoul, South Korea)

Compressional wave attenuation in water-saturated granular medium depends on both the frequency and grain size. In recent series of high frequency measurements on porous medium, such as water-saturated glass beads and marine sediments, the effect of grain size distribution on attenuation has been investigated, and a variety of grain size dependence on attenuation has been reported. Particularly, dispersion relation in the granular medium with bimodal grain size distribution is significantly different from that in the medium with unimodal grain size distribution. In this study, two sets of glass beads experiments employing unimodal and bimodal grain size distributions are performed. In order to examine wave propagation phenomenon in the bimodal grains, the attenuation dispersion is represented as a function of three parameters; porosity, volume fraction of scatterers, and Rayleigh parameter *kd*. Heuristic dispersion model considering scattering phenomenon will also be discussed for comparison with measurements.

9:15

5aUW6. Equations describing finite-amplitude effects in acoustic fish abundance estimation. Per Lunde (Univ. of Bergen, Allegaten 55, Bergen N-5020 Bergen, Norway, per.lunde@ift.uib.no)

Species identification of fish and abundance estimation of zooplankton employ frequencies typically in the range of 20–400 kHz. Estimates are based on measurement of (a) the single-target backscattering cross section, σ_{bs}, used in echo sounder calibration and fish target strength measurements; and (b) the volume backscattering coefficient, s_v, used in oceanic surveying. The power budget equations used today for σ_{bs} and s_v preassume small-amplitude signals (i.e., linear sound propagation). For operating frequencies about 100 kHz and higher, finite-amplitude (nonlinear) sound propagation effects in seawater may cause measurements errors at accessible echo sounder transmit power levels. In the present work, power budget equations are derived for σ_{bs} and s_v that account for finite-amplitude sound propagation effects. The expressions derived can be used to establish upper limits for echo sounder transmit power levels, in order to reduce finite-amplitude errors in calibration and surveying. They can alternatively be used to develop correction factors for calibration and/or survey data already subjected to finite-amplitude errors. The expressions derived are fully consistent with the small-signal expressions used in fisheries acoustics today.

9:30

5aUW7. A cavitation threshold for transient signals applied to laboratory-scale sparker-induced pulses. J. James Esplin (Acoust., Penn State Univ., 201 Appl. Sci. Bldg., University Park, PA 16802, jje166@psu.edu), Benjamin Kim (Appl. Res. Lab., Penn State Univ., University Park, PA), and R. Lee Culver (Appl. Res. Lab., Penn State Univ., State College, PA)

The phenomenon known as cavitation can occur when a volume of liquid is subjected to a pressure that falls below a "cavitation threshold". Following this cavitation inception, a rupturing of the fluid or rapid growth of microbubbles occurs. The cavitation threshold is typically thought to be equal to the vapor pressure of the fluid; however, laboratory experiments involving underwater high-amplitude sparker-induced pulses have demonstrated that this is not necessarily the case. This presentation introduces a generalized threshold for transient acoustic pulses based on previous work of a threshold for constant-frequency transient signals. The output of this transient cavitation threshold will be compared against simulation and experiment.

9:45

5aUW8. Nonlinear acoustic pulse propagation in ocean waveguides containing an elastic seabed. Joseph T. Maestas (Appl. Mathematics & Statistics, Colorado School of Mines, 1500 Illinois St., Golden, CO 80401, jmaestas@mines.edu) and Jon M. Collis (Lincoln Lab., Lexington, MA)

High intensity underwater sources, such as explosions, generate nonlinear finite-amplitude pulses that behave differently than linear acoustic pulses within shallow water waveguides. The nonlinearity is known to decrease the critical angle for total internal reflection from that of the linear case when the seafloor is approximated as a fluid. However, this result has not been extensively studied for elastic seafloors where shear waves are present. In this work, a time-domain model is developed assuming an isotropic linear elastic bottom, inviscid water column, and allowing for nonlinear advective acceleration and a nonlinear equation of state. The model is numerically implemented using a high-order Godunov scheme and then benchmarked against tank experiment data for the linear case. The nonlinear model is used to study the critical grazing angle for ocean bottoms of varying shear speeds to determine the combined effect of nonlinearity and elasticity on bottom penetration.

10:00–10:15 Break

10:15

5aUW9. Estimation of cylinder orientation using autonomous underwater vehicle mapping of bistatic scattered fields. Erin M. Fischell and Henrik Schmidt (Mech. Eng., MIT, 77 Massachusetts Ave., 5-204, Cambridge, MA 02139, emf43@mit.edu)

When an aspect-dependent target is insonified by an acoustic source, distinct features are produced in the resulting bistatic scattered field. These features were exploited in a process for estimating target aspect angles that was demonstrated on a real-world data set using models produced using simulation data. Bistatic scattering data was collected during an experiment in November 2014 in Massachusetts Bay using a ship-based acoustic source producing 7-9kHz LFM chirps and a steel pipe target. The true target orientation was unknown, as the target was dropped from the ship with no rotation control. The Autonomous Underwater Vehicle (AUV) Unicorn, fitted with a 16-element nose array and data acquisition payload, was deployed in broadside data collection behaviors around the target, and the ship was moved to create two target aspects. Scattering data was collected for each target aspect angle. A Support Vector Machine (SVM) regression model was trained using simulated scattering bistatic field data from the OASES-SCATT simulation package. This model was used to estimate the target aspect angles using the real data collected by the AUV during the experiment. The aspect angle estimates were consistent with experimental observations of relative source positioning based on ship position.

10:30

5aUW10. Extending the distributed-basis transition matrix for acoustic target scattering to highly oblate elastic objects in free-field. Raymond Lim (Naval Surface Warfare Ctr. Panama City Div., 110 Vernon Ave., Code X11, Panama City, FL 32407-7001, raymond.lim@navy.mil)

In previously presented work, a variant of Waterman's transition (T) matrix utilizing an ansatz for problematic outgoing basis functions in standard formulations was proposed and demonstrated to improve the stability of free-field acoustic scattering calculations for elongated axisymmetric elastic objects. The ansatz replaced the basis causing instability with a non-local basis consisting of low-order spherical functions made into a complete set by distributing the functions along the axis within the object. Unfortunately, as pointed out by Doicu, *et al*. [*Acoustic & Electromagnetic Scattering Analysis Using Discrete Sources*, Academic Press, London, 2000], these bases are not as useful for expanding surface fields on oblate axisymmetric shapes. However, they suggested an alternative basis for such shapes in the form of low-order spherical functions made complete by analytically continuing them into a complex plane of the axial coordinate of the object and distributing them along the imaginary axis of this axial coordinate. This presentation will show how this alternative performs in our T-matrix formulation for highly oblate axisymmetric objects, discuss sources of residual noise, and suggest ways to remediate the noise for such shapes. [Work supported by ONR.]

10:45

5aUW11. Scattering from a partially buried target: A modified acoustic ray model. Steven G. Kargl, Aubrey L. Espana, and Kevin L. Williams (Appl. Phys. Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, kargl@uw.edu)

An acoustic ray model, recently presented by Kargl *et al*. (*IEEE J. Ocean. Eng*., DOI: 10.1109/JOE.2014.2356934), describes the scattering of sound from a target within a homogeneous waveguide. For a proud target, four ray paths account for the interaction of incident sound with the target and its local environment. In marine environments, a target at the water-sediment boundary can be partially or completely buried. Ray paths that may reach a target then depend on the burial state. Modifications to the ray model are presented. The simplest approach introduces a Heaviside step function into the model, which abruptly turns a ray contribution off as a ray's point of impact on a target transitions from above the boundary to below. In geometric acoustics, the Heaviside step function is a zeroth order approximation to the Fresnel integral for the diffraction of sound at a shadow boundary into a shadow region. The Fresnel integral provides a smooth transition in the intensity across the boundary. Similarly, a smooth transition should occur within a modified ray model for partially buried targets. The modified ray model will be compared to finite-element model results for a solid aluminum cylinder and an aluminum replica of a underwater unexploded ordnance. [Research supported by SERDP and ONR.]

11:00

5aUW12. Deep ocean vector sensor array performance metrics. Gabriel P. Kniffin and Lisa Zurk (Elec. and Comput. Eng., Portland State Univ., P. O. Box 751 - ECE, Portland, OR 97207, kniffing@pdx.edu)

Recent work in passive sonar has drawn interest in the potential for vertical line arrays (VLAs) deployed below the critical depth—the depth in the deep ocean at which the sound speed below the channel axis reaches the sound speed near the surface. Such arrays can take advantage of propagation via the reliable acoustic path (RAP), which has been shown to improve the signal-to-noise ratio (SNR) of received signals from sources at or near the surface at moderate ranges. The potential of these deep ocean VLAs has spawned further interest in the design of vector sensor VLAs that would allow azimuthal rejection and additional array gain over conventional pressure sensor VLAs. This work will present simulation results that explore and quantify the performance of such vector sensor VLAs deployed in the deep ocean in terms of surface area coverage, detection probability, and operational lifetime. The potential use of these deep ocean vector sensor arrays to estimate source depth using the depth-harmonic interference between direct and surface-reflected acoustic arrivals will also be discussed.

11:15

5aUW13. Space-time block coding for undersea acoustic links. Sabna N, Revathy R, and P. R. S. Pillai (Dept. of Electronics - CUCENTOL Lab, Cochin Univ. of Sci. and Technol., CUCENTOL Lab, Ernakulam, Kerala 682022, India, sabnan@yahoo.com)

Current research in undersea communication scenario focuses on the applications of undersea acoustic networks in environmental data collection, pollution monitoring, offshore surveillance, coastal surveillance, etc. The various constraints encountered in undersea acoustic communications are mainly low bandwidth, high latency, high failure rates of acoustic links, and multipath propagation effects. Multipath effects in undersea environments are due to the reflection of sound by the sea surface and sea bottom as well as refraction of sound in water. As a result, the receiver gets a bewildering mix of signals. The receiving subsystems of the undersea networks perform special signal processing techniques for regenerating the data streams from the multipath composite signals in a MIMO configurable network. The performance of Space-Time Block Coding (STBC) diversity technique has been adopted in this paper for improving the reliability of the undersea network. In the simplest form of MIMO configuration, two transmitting transducers send out the data stream and its modified versions in two time slots on independently fading environments, leading to substantial improvements in the error rate performance. For a shallow water medium range channel, which exhibits the Rayleigh fading characteristics, the error rate performance has been found to be 7×10^{-6} for 16-QAM based STBC.