PROGRAM OF

The First Pan-American/Iberian Meeting on Acoustics • Cancun, Mexico
2–6 December 2002

NOTE: All Journal articles and Letters to the Editor are peer reviewed before publication. Program abstracts, however, are not reviewed before publication, since we are prohibited by time and schedule.

MONDAY MORNING, 2 DECEMBER 2002 GRAND CORAL 1 AND 2, 9:30 TO 11:30 A.M.

Opening Ceremonies

Introduction of Choir

Welcoming Remarks

Dr. Juan Ignacio Garcia Salvidea, Mayor of Cancun, Mexico

Richard Stern, President, Acoustical Society of America

James E. West, Meeting Cochair, Acoustical Society of America

Samir N. Y. Gerges, Meeting Cochair and President, Iberoamerican Federation of Acoustics

Sergio Beristain, Meeting Cochair and President, Mexican Institute of Acoustics

MONDAY AFTERNOON, 2 DECEMBER 2002 GRAND CORAL 2, 1:30 TO 3:05 P.M.

Session 1pAAa

Architectural Acoustics and Noise: Design of Offices to Enhance Speech Privacy and Work Performance

Kenneth P. Roy, Chair
Innovation Center, Armstrong World Industries, P.O. Box 3511, Lancaster, Pennsylvania 17604

Chair's Introduction—1:30

Invited Papers

1:35

1pAAa1. Designing for speech privacy in offices. Kenneth P. Roy (Armstrong World Industries, Innovation Ctr., 2500 Columbia Ave., Lancaster, PA 17603)

Speech privacy is an important component of the building interior environment, as it affects the satisfaction and performance of the occupants and thus their productivity. Privacy, both in terms of the confidentiality of conversations and relative to distractions and annoyance, needs to be considered. Field measurements of interzone attenuation, S/N ratio, and privacy calculations will be presented for various open and closed office designs from evaluations in several buildings. Field sound measurement techniques, and electronic masking system design and tuning will be discussed.

2:00

1pAAa2. Design variables for speech privacy in offices. Joel A. Lewitz (Lewitz and Assoc., Inc., 1505 Bridgeway, Ste. 128, Sausalito, CA 94965)

Open plan office environments have a lower potential for speech privacy and freedom from distraction than conventional enclosed offices. The three areas of concern for the acoustical designer are the source, path and listener environments. Given a source spectrum, level and directivity, design elements, which influence attenuation paths, will be addressed with evaluations of their relative importance. The spectrum, level, uniformity and incoherence of background sound at the listener are critical to establishing adequate signal-to-noise ratio for high privacy criteria. Case studies will be addressed comparing challenges, solutions, and results for various open and closed plan spaces. These will be compared to a computer model, which evaluates the relative contribution to privacy of the most important open plan office design variables. Sound masking was shown to be the most powerful and cost effective design tool for establishing acoustical environments with varying privacy criteria.

2:25

1pAAa3. The influence of spatialized background noise on ease of hearing in rooms. Yasushi Shimizu, Abigail Stefaniw, Dana Smith, and Rendell Torres (Prog. in Architectural Acoust., School of Architecture, Rensselaer Polytechnic Inst., Troy, NY 12180)

The influence of irrelevant noise on worker's performance has not yet been studied from the standpoint of spatialized background noise in rooms. This paper presents the detriment to Ease of Hearing due to spatial auditory events produced by intruding sound in open plan offices. Auralization is used to represent a generic open plan office noise environment that includes HVAC noise, an intruding voice, and a focus voice. Two different speech communication environments are presented to the listener. In the first presentation, the intruding voice is located far from the listener's workstation (in the reverberant field) and is not localizable. In the second presentation, the intruding voice is localized near the listener's workstation. The focus voice is localized in front of the listener for both presentations. These sounds are played over a five-channel auralization system. Listeners are tested for the degree of Ease of Hearing (EOH) of the focus voice. Psycho-acoustical test results are presented to show the difference between the Ease of Hearing in each case. Improvement strategies to keep high quality communication are also presented based on the results.

Contributed Paper

2:50

1pAAa4. ClassTalk system for predicting and visualizing speech in noise in classrooms. Murray Hodgson (School of Occupational and Environ. Hygiene, Univ. of British Columbia, 3rd Fl., 2206 East Mall, Vancouver, BC V6T 1Z3, Canada)

This paper discusses the ClassTalk system for modeling, predicting and visualizing speech in noise in classrooms. Modeling involves defining the classroom geometry, sources, sound-absorbing features, and receiver positions. Empirical models, used to predict speech and noise levels, and reverberation times, are described. Male or female speech sources, and overhead-, slide-, or LCD-projector, or ventilation-outlet noise sources, can have four output levels; values are assigned based on ranges of values found from published data and measurements. ClassTalk visualizes the floor plan, speech- and noise-source positions, and the receiver position. The user can walk through the room at will. In real time, six quantities—background-noise level, speech level, signal-to-noise level difference, useful-to-detrimental energy fraction (U50), Speech Transmission Index, and speech intelligibility—are displayed, along with occupied and unoccupied reverberation times. An example of a large classroom before and after treatment is presented. The future development of improved prediction models and of the sound module, which will auralize speech in noise with reverberation, is discussed.

MONDAY AFTERNOON, 2 DECEMBER 2002 GRAND CORAL 2, 3:20 TO 4:50 P.M.

Session 1pAAb

Architectural Acoustics and Noise: Acoustical Design at Hotels

David E. Marsh, Chair
Pelton Marsh Kinsella, 1420 West Mockingbird Lane, Suite 400, Dallas, Texas 75247-4932

Invited Papers

3:20

1pAAb1. Design challenges and coordination issues in hotel projects. Melvin L. Saunders IV and David Marsh (Pelton Marsh Kinsella, 1420 W. Mockingbird Ln., Dallas, TX 75247, saundersml@c-b.com)

The design of a Five Star hotel facility encompasses a myriad of design dilemmas. On the same note, the design of a One Star or Two Star hotel has many dilemmas of its own. The ability of an acoustical consultant, as an integral part of the design team, to recognize the differences between these types of projects can be the difference between a successful hotel project and miserable failure. Different quality hotels require different levels of design criteria. Proper coordination and timing between trades and installations, such as loudspeakers, ceiling coffers, chandeliers, sprinkler heads, and ductwork, is also very important for the success of the overall project. This paper will discuss techniques and methods to produce successful hotel projects, as well as various noise sources throughout these spaces. It will also highlight a number of tips learned through many hotel design experiences.

3:45

1pAAb2. Structure-borne noise at hotels. George Paul Wilson and Deborah A. Jue (Wilson, Ihrig & Assoc., Inc., 5776 Broadway, Oakland, CA 94618-1531, gwilson@wiai.com)

Hotels present a challenging environment for building designers to provide suitable noise and vibration isolation between very incompatible uses. While many are familiar with ways to reduce traditional sources of airborne noise and vibration, structure-borne noise and vibration are often overlooked, often with costly repercussions. Structure-borne noise can be very difficult to pinpoint, and troubleshooting the sources of the vibration can be a tedious process. Therefore, the best approach is to avoid the problem altogether during design, with attention to the building construction, potential vibration sources, building uses and equipment locations. In this paper, the relationship between structure-borne vibration and noise are reviewed, typical vibration sources discussed (e.g., aerobic rooms, laundry rooms, mechanical equipment/building services, and subway rail transit), and key details and design guidance to minimize structure-borne noise provided.

4:10

1pAAb3. The isolation of low frequency impact sounds in hotel construction. John J. LoVerde and David W. Dong (Veneklasen Assoc., 1711 Sixteenth St., Santa Monica, CA 90404)

One of the design challenges in the acoustical design of hotels is reducing low frequency sounds from footfalls occurring on both carpeted and hard-surfaced floors. Research on low frequency impact noise [W. Blazier and R. DuPree, J. Acoust. Soc. Am. **96**, 1521–1532 (1994)] resulted in a conclusion that in wood construction low frequency impact sounds were clearly audible and that feasible control methods were not available. The results of numerous FIIC (Field Impact Insulation Class) measurements performed in accordance with ASTM E1007 indicate the lack of correlation between FIIC ratings and the reaction of occupants in the room below. The measurements presented include FIIC ratings and sound pressure level measurements below the ASTM E1007 low frequency limit of 100 Hertz, and reveal that excessive sound levels in the frequency range of 63 to 100 Hertz correlate with occupant complaints. Based upon this history, a tentative criterion for maximum impact sound level in the low frequency range is presented. The results presented of modifying existing constructions to reduce the transmission of impact sounds at low frequencies indicate that there may be practical solutions to this longstanding problem.

Contributed Paper

4:35

1pAAb4. Meeting space acoustics. Paul L. Tan (Shen Milsom & Wilke, Inc. (Las Vegas), 5729 Bracana Court, Las Vegas, NV 89141)

A general synopsis of acoustic requirements in large dedicated, or multiuse spaces in entertainment, such as casinos, hotels, and themed restaurants is presented. This paper will explore various acoustical performance criteria such as building system noise and vibration, space volume, architectural geometry, sound isolation, and factors influencing speech and music intelligibility, such as reverberation, echoes, etc., Also included in this exploration will be the integration of modern 21st century multimedia and telecommunications technology.

MONDAY AFTERNOON, 2 DECEMBER 2002 CORAL KINGDOM 2 AND 3, 1:00 TO 5:40 P.M.

Session 1pAB

Animal Bioacoustics: Coral Reef Bioacoustics

David Mann, Chair

College of Marine Science, University of South Florida, 140 Seventh Avenue South, Saint Petersburg, Florida 33701

Chair's Introduction—1:00

Invited Papers

1:05

1pAB1. Diversity of fish courtship and spawning sounds and application for monitoring reproduction. Phillip Lobel (Boston Univ. Marine Prog., Marine Biological Lab., Woods Hole, MA 02543)

It has been known for a long time that many fishes produce sounds especially during reproduction. Recent studies using a novel system for synchronous audio and video recordings underwater reveal that several species produce species specific and behavior specific sounds exclusively associated with courtship and the mating act. Passive acoustic technology can utilize these sounds to remotely monitor the breeding behavior of reef fishes. This application is being tested as an alternative or supplement to the traditional methods involving sampling fish gonads, ichthyoplankton net collection, and direct observation by scuba diving. This presentation will show a video with sounds of fishes courting and spawning and will describe their acoustic characteristics.

1:25

1pAB2. Acoustic competition in the gulf toadfish *Opsanus beta*. Michael L. Fine and Robert F. Thorson (Dept. of Biol., Virginia Commonwealth Univ., Richmond, VA 23284-2012, mfine@atlas.vcu.edu)

Nesting male *Opsanus beta* produce boatwhistle advertisement calls and agonistic grunt calls. The grunt is a short-duration pulsatile call, and the boatwhistle is a complex call typically consisting of zero to three introductory grunts, a long tonal boop note, and zero to three shorter boops. The beginning of the boop note is also gruntlike. Anomalous boatwhistles contain a short duration grunt embedded in the tonal portion of the boop or between an introductory grunt and the boop. Embedded grunts have sound pressure levels and frequency spectra that correspond with those of recognized neighbors, suggesting that one fish is grunting during another's call, a phenomenon here termed acoustic tagging. Snaps of nearby pistol shrimp may also be tagged, and chains of tags involving more than two fish occur. The stimulus to tag is a relatively intense sound with a rapid rise time, and tags are generally produced within 100 ms of a trigger stimulus. Time between the trigger and the tag decreases with increased trigger amplitude. Tagging is distinct from increased calling in response to natural calls or stimulatory playbacks since calls rarely overlap other calls or playbacks. Tagging is not generally reciprocal between fish suggesting parallels to dominance displays.

1:45

1pAB3. Nocturnal sound production by longspine squirrelfish (*Holocentrus rufus*) with notes on sound production by fishes on the Turneffe Atoll coral reef in Belize. Joseph Luczkovich, Christopher Stewart (Dept. of Biol., East Carolina Univ., Greenville, NC 27858), and Mark Sprague (East Carolina Univ., Greenville, NC 27858)

Reef fishes produce sounds in response to disturbance, during agonistic encounters in defense of territories, and in spawning events. We recorded in captivity the disturbance sounds of reef fishes in the grunt family (*Haemulidae*), triggerfish family (*Balistidae*), and squirrelfish family (*Holocentridae*) in Belize. Using these recordings and published sonograms for reef fishes, we have identified longspine squirrelfish (*Holocentrus rufus*) in field recordings made on Calabash Caye, Turneffe Atoll, in Belize. We monitored the production of sound by longspine squirrelfish over the course of a transition from day to night. The calling rate of the longspine squirrelfish was greatest after sunset, suggesting that the increased activity of these fish was due to their nocturnal agonistic behavior. A sonobuoy that recorded on a timer 90 s every hour for 24 h failed to detect any longspine squirrelfish calls, perhaps due to their intermittent nature. An unknown sound of biological origin was detected on the sonobuoy recording, but it did not match any of the captive species recorded. A reef fish sound catalogue from captive individuals is being collected for use in the identification of unknown sounds and to monitor the condition of the reefs remotely.

2:05

1pAB4. Snapping shrimps: The bane of bioacoustics monitoring of coral reefs. Whitlow W. L. Au (Hawaii Inst. of Marine Biol., P.O. Box 1106, Kailua, HI 96734)

Snapping shrimps are the major source of biological noise in shallow bays, harbors, inlets, and coral reefs in temperate and tropical waters. The sounds are impulsive with a very broad spectrum spanning from several hundred Hz to over 200 kHz. Peak frequencies are typically between 1–10 kHz with a very slow drop-off in energy with increasing frequency. At 200 kHz, the intensity of the sound may be only 20 dB below the intensity at the peak frequency. The peak-to-peak source level can be higher than approximately 189 dB *re* 1 mPa. When a shrimp rapidly closes its snapper claw, a high-velocity water jet that has speed exceeding cavitation conditions is produced. The sound is the result of a cavitating bubble collapsing. In a body of water, the overall level of snapping shrimp sounds can be as high as 20 dB above the noise level typical of sea state 6. The noise is present continuously, with little diurnal and seasonal variations and its broad frequency extent make it extremely difficult to filter this noise. Therefore, snapping shrimp sounds can severely limit the use of underwater bioacoustic monitoring in a coral reef environment.

Contributed Papers

2:25

1pAB5. Choruses from fishes in the Great Barrier Reef. Robert D. McCauley (Ctr. for Marine Sci. and Tech., Curtin Univ. of Technol., Bentley, WA 6102, Australia) and Douglas H. Cato (Defence Sci. and Technol. Organisation, Pyrmont 2009, Australia)

Sounds from fish and invertebrates are a major component of the ambient sea noise around Australia, particularly within the Great Barrier Reef. Choruses from large numbers of calling animals are common and cause large variations in noise level. Long term statistics from the central Great Barrier Reef showed fish calling was a major contributor, both as continuous choruses and as individual calls repeated frequently. Four calling types predominated, with each displaying unique call characteristics and calling patterns through time and space. Durations varied from less than 10 ms to several seconds long, and comprised from one to nearly 40 pulses. These sounds were most common during the Australian summer with one call type also displaying lunar trends. They all showed diurnal variation with the highest activity generally at night, but times of maximum calling rate for each source type differed, consistent with avoiding competition for sound space. The acoustical characteristics of the call types provided information on the fishes calling physiology and behavior. The structure of each pulse could be related to swimbladder mechanics, with swimbladders normally lightly damped. On some occasions, a call type attributed to nocturnal planktivorous fishes may have ensonified much of the Great Barrier Reef.

2:40

1pAB6. Sound production by the toadfish *Sanopus astrifer*. David A. Mann (Univ. of South Florida, College of Marine Sci., 140 7th Ave. S., St. Petersburg, FL 33701, dmann@marine.usf.edu), Wei-Li Diana Ma (Boston Univ., Boston, MA 02215), and Phillip S. Lobel (Boston Univ., Woods Hole, MA 02543)

Sounds produced by the toadfish *Sanopus astrifer* were recorded at Glovers Atoll, Belize. These are the first recorded sounds by a toadfish in the *Sanopus* genus. The boatwhistle call is similar to the boatwhistle produced by *Opsanus* species, in that it consists of a harmonic call about 250 ms in duration with a fundamental frequency of about 180 Hz. Boatwhistles are made in bouts of 1–4 boatwhistles with an inter-boatwhistle interval of 140–170 ms. The first boatwhistle in a bout tends to be longer than subsequent boatwhistles. *S. astrifer* also shows the acoustic tagging phenomenon described by Fine and Thorson for *Opsanus beta*, in which the male produces a short grunt during calling by another male. However, instead of tagging during the boatwhistle like *Opsanus*, *Sanopus* tags between boatwhistles in a bout.

2:55–3:05 Break

Invited Papers

3:05

1pAB7. Sound detection by coral reef fishes. Arthur N. Popper (Dept. of Biol. and Neurosci. & Cognit. Sci. Prog., Univ. of Maryland, College Park, MD 20742, apopper@umd.edu)

Many coral reef fishes use sounds for communication. However, they, as all fishes, learn a good deal about their environment by listening to ambient noises produced by swimming fishes, water moving across the reef, rain, and many other sources. Such information provides these fishes with a sensory world that is far more extensive than from visual, chemical, or tactile cues. There is also a growing body of evidence that suggests that larval coral reef fishes that have not yet settled are able to detect, and swim towards, a reef through the use of the ambient sound of the reef. Studies of hearing by coral reef fishes show considerable variability in sound detection capabilities, sometimes even within the same taxonomic family. Studies have shown that different damsel fishes (*Pomacentridae*) can actually discriminate between sounds produced by their own species and other species within the group. Within the holocentrids, there are similarities in the sounds produced by different species, but considerable differences in the structure of the ear and in hearing capabilities of the same species. This paper will discuss sound detection by coral reef fishes, and the ability of fishes to detect and use the ''auditory scene.''

3:25

1pAB8. The laterophysic connection: A novel specialization thought to enhance sound pressure sensitivity in butterflyfishes (*Chaetodontidae, Chaetodon*). Jacqueline F. Webb (Dept. of Biol., Villanova Univ., Villanova, PA 19087, jacqueline.webb@villanova.edu), W. Leo Smith (American Museum of Natural History, New York, NY), Timothy C. Tricas (Univ. of Hawaii at Manoa, Honolulu, HI 96822), and Darlene R. Ketten (Woods Hole Oceanogr. Inst., Woods Hole, MA 02543)

Morphological specializations that enhance sound reception have been described among fishes, but sources of behaviorally-significant sound stimuli and sound transduction mechanisms are known for very few bony fishes. Butterflyfishes in the genus Chaetodon have a unique sensory specialization, the laterophysic connection (LC), defined anterior swim bladder extensions (horns) in association with medial openings in the lateral line canals of the cranial supracleithral bones. The LC is hypothesized to enhance sensitivity of both the lateral line and ear to sound pressure. Variation in LC morphology among species is defined by variation in soft tissues and is thought to be functionally significant. Preliminary field studies demonstrate that C. multicinctus produces sounds during agonistic interactions, thus providing a source of potentially relevant sound stimuli. Presence of an inflated swim bladder in close proximity to well-developed supracleithral openings in pelagic tholichthys stage individuals (15 mm SL) and horn development at the end of the tholichthys stage (25–29 mm SL) in C. ocellatus suggests that sound may also play an important role in the early life history of Chaetodon. [Work supported by the NSF IBN-9603896 to J.F.W.]

3:45

1pAB9. Larval orientation to reefs and reef sound. John Montgomery, Nicholas Tolimieri (Leigh Marine Lab., Univ. of Auckland, Auckland, New Zealand), and Andrew Jeffs (Natl. Inst. for Water and Atmospheric Res., New Zealand)

Reef systems form a discontinuous spatial mosaic leading many reef organisms to have a dispersal phase in their early life history. At the end of this phase, the larvae must settle onto a reef. Recent evidence supports the view that both larval fish and invertebrates are more active participants in finding suitable settlement habitat than had previously been thought. Not only are they more active swimmers, but field evidence shows that they orient toward reefs from some distance away. Of the possible distance clues, sound is potentially one of the most attractive. Both abiotic and biotic sounds provide habitat-specific information that propagates well underwater and can convey directional clues. Using a combination of reef sound replay, light traps, and choice chambers, it has been shown that larval fish and invertebrates can be attracted to reef sound. Hearing in most fish is based on the otoliths of the inner ear that detect displacement in the sound field. Current theory holds that otolithic hearing is capable of detecting the axis of sound propagation, but not the direction to the source. These experiments provide evidence that fish larvae (even those without a swimbladder) can resolve this 180 degree ambiguity.

4:05

1pAB10. Sound detection of reef sounds by larvae of coral-reef fishes. Jeffrey M. Leis, Brooke M. Carson-Ewart (Australian Museum, 6 College St., Sydney, NSW 2010, Australia, jeffl@austmus.gov.au), and Douglas H. Cato (Defence Sci. and Technol. Organisation, Pyrmont 2009, Australia)

Nearly all teleost reef fishes are pelagic during the larval stage, returning at the end of this stage to settle in a reefal habitat. Little is known about their sensory capabilities or how larvae detect and locate a reef. Sound is the most likely cue, particularly since reef shrimp and fish choruses are audible at considerable distances. Playback experiments off Lizard Island, Great Barrier Reef, broadcast nocturnal reef sounds and artificial sounds (pure tones) in the presence of settlement stage larvae of the coral-reef damselfish *Chromis atripectoralis*, released during the day within 100 m of the underwater speaker 500–1000 m from the nearest reef. Larvae consistently swam to the south in the absence of playback and during playback of artificial sounds. During playback of reef sounds, they showed

no overall swimming direction, indicating that they can hear and can distinguish between a sound with potential biological significance and one without. Light traps with and without playback of reef sounds on 33 paired (playback: nonplayback) trap nights resulted in higher catches for 14 of 17 families for which >10 individuals were trapped. This suggests that not only can larvae hear, but they also have some aural localization capability.

4:25

1pAB11. Ontogenetic development of mechanosensory ability of a pomacentrid coral fish, the red saddleback clownfish (*Amphiprion ephippium*). Hong Yan (School of Biological Sci., Univ. of Kentucky, Lexington, KY 40506-0225, hyyan00@pop.uky.edu), Steve Simpson (Dept. of Biol., Univ. of York, P.O. Box 373, York YO10 5YW, UK), and Matthew Wittenrich (East Aurora, NY 14052)

Recent work on the settlement of coral reef fish suggests that ambient sound could be used as a cue for navigation by the pelagic larvas of reef fishes. Coral reef fish larvas made directional movements toward sound stimulus indicating they are capable of detecting and localizing sound. These findings suggest that some degrees of hearing abilities must have developed prior to settlement. We used embryos and newly hatched larvas of a clown fish (*Amphiprion ephippium*) to investigate the ontogenetic development of the auditory function of this fish. The heart beat rates of embryos and newly hatched larvas (up to 7 days after hatching) in response to various frequencies of sound were measured to indicate their reaction to mechanosensory stimuli. The auditory brainstem response (ABR) recording protocol was used to measure acoustically evoked potentials of Day-8 to Day-36 larvas. Preliminary findings indicate that both the embryos' and larvas reaction to sound stimuli improved (both frequency range and sound pressure level) throughout the development. The electrophysiological observations on embryos and larvas of Amphiprion ephippium provide evidence to support the hypothesis that acoustic stimuli could be used as a cue for coral reef larval fish migration use. [Work supported by NIH, NOHR, IMLS, NERC, AIMS.]

4:45

1pAB12. The application of passive acoustics to assess, monitor, and protect the coral reef ecosystems of the U.S. Pacific Islands. Russell E. Brainard, Kevin B. Wong (NOAA Fisheries, Honolulu Lab., 1125-B Ala Moana Blvd., Honolulu, HI 96825), Scott Ferguson, and Molly Timmers (Joint Inst. for Marine and Atmospheric Res., Univ. of Hawaii)

Activities of the NOAA Fisheries Honolulu Laboratory Coral Reef Ecosystem Investigation (CREI) are presented and areas where the application of passive acoustic methods may significantly contribute to scientific, management, and operational objectives are highlighted. To understand coral reef ecosystems and to reduce adverse human impacts are two fundamental themes of The National Action Plan to Conserve Coral Reefs. The CREI was established to assess, monitor, map, restore, and protect the coral reef ecosystems of the U.S. Pacific Islands. Activities include rapid ecological assessments of fish, corals, algae, and invertebrates, digital video surveys of habitat and fish, acoustic seabed classification surveys, an *in-situ* collection of oceanographic conditions, and satellite remote sensing observations. Resource constraints and the large distances between the U.S. Pacific Islands often limit *in-situ* work to 1–2 years between site visits and prevent adequate temporal monitoring of the biological responses. We propose to develop passive acoustic techniques to monitor some aspects of the health of these remote ecosystems and to develop warning systems to elert scientists and resource managers of large changes or potential threats.

5:05

1pAB13. Analysis of coral reef sound recordings in the Phoenix and Line Islands. Mark W. Sprague, Joseph J. Luczkovich (East Carolina Univ., Greenville, NC 27858, spraguem@mail.ecu.edu), Russell E. Brainard, and Kevin B. Wong (NOAA Fisheries, Honolulu Lab., Honolulu, HI 96814)

Automated acoustic recording stations are being considered to allow managers to monitor remote coral reefs. Sounds of interest include those of biological, environmental, and anthropogenic origin. Preliminary data about remote acoustic monitoring of reefs were obtained in February–March of 2001 and 2002 during National Oceanic and Atmospheric Administration (NOAA) cruises to the Phoenix and Line Islands in the western Pacific Ocean. In 2001, sonobuoys manufactured by East Carolina University (ECU) were deployed to make a 90-s acoustic recording every hour for a 24-h period at each location. In 2002, continuous 24-h acoustic recordings were made using an experimental Remote Underwater Digital Acoustic Recording (RUDAR) system. The ECU sonobuoys recorded diurnal and locational variations in the sounds of snapping shrimp as well as variations in ambient noise. At most locations, the snapping shrimp sound level increased near sunset and decreased near sunrise. The experimental RUDAR system recorded limited data due to some technical problems arising from field use. Analysis of the recordings as well as recommendations for future studies will be presented.

Contributed Paper

5:25

1pAB14. The importance of sound for navigation at settlement in coral reef fishes, with reference to the development of the auditory response. Stephen D. Simpson (Dept. of Biol., Univ. of York, P.O. Box 373, York YO10 5YW, UK), Matthew L. Wittenrich (1256 Luther Rd., East Aurora, NY 14052), Mark G. Meekan (Australian Inst. of Marine Sci., Darwin, NT 0909, Australia), and Hong Y. Yan (Univ. of Kentucky, Lexington, KY 40506)

The behavioral mechanisms that larval coral reef fishes employ to locate suitable settlement habitats on their return from the plankton are poorly understood. The response of settlement-stage reef fishes to reef noise was studied at Lizard Island, Great Barrier Reef, Australia. Catches of fishes in light traps attached to underwater speakers playing reef sounds were twice those of silent traps. To demonstrate that this attraction is important during settlement, sound was used to favorably attract settlers to noisy (over silent) artificial reefs. Many coral reef fish families lay eggs demersally on the reef. By monitoring the heart rates of clownfish embryos in response to artificial noise signals, a broadening of the spectral range of response and a lowering of the threshold of response (an increase in sensitivity) was identified during their development. The thresholds suggest that these embryonic fish will have experienced coral reef noises

prior to leaving the reef. These studies clearly demonstrate the use of sound as a navigation cue for settlement-stage coral reef fishes, and suggest the potential for imprinting. Our findings not only have major implications for how we model recruitment, but also offer some potential management tools for reef systems. [Work supported by Natural Environment Research Council (UK), British Association, Australian Institute of Marine Science, National Organization for Hearing Research (USA), Institute of Museum and Library Services (USA), Department of Education (USA).]

MONDAY AFTERNOON, 2 DECEMBER 2002 CORAL GARDEN 2 AND 3, 1:00 TO 5:40 P.M.

Session 1pAO

Acoustical Oceanography and Underwater Acoustics: David Weston Memorial Session I

D. Vance Holliday, Cochair
BAE Systems, 4669 Murphy Canyon Road, Suite 102, San Diego, California 92123-4333

Ian Roebuck, Cochair
DSTL Naval Systems, Winfrith Technology Center, Dorchester, Dorset DT2 8WX, United Kingdom

Chair's Introduction—1:00

Invited Papers

1:05

1pAO1. Formulas for signal and reverberation with mode-stripping and Lambert's law. Chris H. Harrison (SACLANT Undersea Res. Ctr., Viale San Bartolomeo, 400, 19138 La Spezia, Italy, harrison@saclantc.nato.int)

Extending David Weston's notion of ray invariants and flux it is possible to derive closed-form solutions for two-way propagation and reverberation in range-dependent ducts. In particular, there is interesting and sometimes surprising behavior when the propagation obeys ''mode-stripping'' (the high angles are preferentially attenuated by bottom losses) while the scattering obeys Lambert's Law (high angles are preferentially backscattered). There is a regime where reverberation and target follow the same range law, postponing ''reverberation-limiting'' indefinitely! From the experimental and databasing point of view it is therefore extremely important to know whether Lambert's Law is actually obeyed in practice. These issues and their implications for signal-to-background are addressed. The formulas allow for range-dependent environments and the transition from mode-stripping to single mode propagation at long range. A modified version for range-independent environments includes the effects of refraction on reverberation and signal-to-background. While these formulas cannot compete with numerical calculations in terms of detail, they show at a glance the dependence on such parameters as bathymetry, critical angle, bottom loss (within the critical angle). Here, the behavior is illustrated graphically and compared with a numerical model, SUPREMO.

1:25

1pAO2. David Weston—Ocean science of invariant principles, total accuracy, and appropriate precision. Ian Roebuck (DSTL, Winfrith Technol. Ctr., Dorchester, Dorset DT2 8WX, UK, iroebuck@dstl.gov.uk)

David Weston's entire professional career was as a member of the Royal Navy Scientific Service, working in the field of ocean acoustics and its applications to maritime operations. The breadth of his interests has often been remarked upon, but because of the sensitive nature of his work at the time, it was indeed much more diverse than his published papers showed. This presentation, from the successors to the laboratories he illuminated for many years, is an attempt to fill in at least some of the gaps. The presentation also focuses on the underlying scientific philosophy of David's work, rooted in the British tradition of applicable mathematics and physics. A deep appreciation of the role of invariants and dimensional methods, and awareness of the sensitivity of any models to changes to the input assumptions, was at the heart of his approach. The needs of the Navy kept him rigorous in requiring accuracy, and clear about the distinction between it and precision. Examples of these principles are included, still as relevant today as they were when he insisted on applying them 30 years ago.

1:45

1pAO3. Wavefront modeling in shallow water acoustics. Chris T. Tindle (Phys. Dept., Univ. of Auckland, Auckland, New Zealand)

Early work in collaboration with David Weston on the relationship between ray and normal mode propagation led to ray theory with beam displacement which showed that ray based solutions were not restricted to high frequencies. In turn this has led to acoustic wavefront modeling which allows the efficient calculation of transient acoustic fields in conditions of rapid range dependence. In wavefront modeling, conventional ray tracing is used to find the wavefronts but the amplitude, phase, and travel time of pulses are found from a depth−time diagram at the receiver range. The method allows for rapidly changing water depth due to surface waves. Reflection of sound beneath surface wave crests leads to focusing and caustics which are handled through approximations to a phase function. There is good agreement with experimental results. [Work supported by ONR.]

2:05

1pAO4. Sound absorption due to fish: From David Weston's discoveries to recent developments. Orest Diachok (Naval Res. Lab., Washington, DC 20375, orest@wave.nrl.navy.mil)

David Weston's experiments in the early 1960's on sound propagation between bottom mounted sources and receivers led to an unexpected result: transmission loss in limited frequency bands changed abruptly during twilight. The magnitude of the change: as large as 40 dB at 20 km. Temporal changes in absorption losses coincided with the times when the character of backscattered signals changed from discrete echoes during daytime, to diffuse reverberation at night. Weston's hypotheses: both effects were due to fish with swim bladders, and diurnal changes in the attenuation and reverberation were due to changes in the depth and separation between fish in schools. Weston's discoveries and inferences provided the stimulus for the design of multi-disciplinary ''bioacoustic absorption spectroscopy'' experiments in 1995 in the Gulf of Lion in concert with Ifremer, France (Diachok, 1999), and in 2001 in the Santa Barbara Channel in concert with the Southwest Fisheries Science Center, USA (Diachok *et al.,* 2002). These experiments provided compelling evidence of (1) the biological causes of absorption lines, (2) frequency changes associated with changes in depth and separation at twilight, and (3) good agreement between number densities derived from concurrent absorptivity and fisheries echo sounder measurements. [Research supported by ONR.]

2:25

1pAO5. The contributions of David Weston to the acoustics of gas-filled bladders in fishes. Mardi C. Hastings (Biomed. Eng. Ctr. and Dept. of Mech. Eng., Ohio State Univ., 1080 Carmack Rd., Columbus, OH 43210, hastings.6@osu.edu)

Thirty-five years ago David Weston published ''Sound Propagation in the Presence of Bladder Fish'' [in *Underwater Acoustics*, Vol. 2, edited by V. M. Albers, 1967, pp. 55–88], a seminal contribution that provided the foundation for future research pertaining not only to scattering by fish, but also swimbladder mechanics. In this paper he outlined the theory for the acoustic response of a single swimbladder and then extrapolated to estimate scattering of sound by large schools of fish in the ocean. He addressed the effects of swimbladder geometry, tissue surrounding the swimbladder, and ocean depth on its resonance and scattering characteristics. At that time he pointed out that his work was primarily theoretical because very few experiments had been reported. In the last two decades advances in instrumentation and continued interest in this subject have led to many experiments that have provided data that now confirm much of his original theory. A review of experimental studies inspired by his work and correlation of data with his creative theoretical predictions will be presented.

Contributed Paper

2:45

1pAO6. Three applications of David Weston's work to studies of scattering from fish. C. Feuillade, R. W. Nero, C. H. Thompson (Naval Res. Lab., Stennis Space Center, MS 39529-5004), and R. H. Love (BayouAcoust., Pass Christian, MS 39571-2111)

The Naval Research Laboratory has for many years conducted a program, comprising both experimental and theoretical components, to determine the low- to mid-frequency acoustic scattering characteristics of individual fish and fish schools. This paper discusses three procedures, developed during the course of our work, whose intellectual genesis can be traced directly from David Weston. First, we discuss the ''Weston correction'' to the monopole resonance frequency of a prolate spheroidal air bubble. This is used to model variations in the resonance frequency of a fish swimbladder as its aspect ratio changes under compression, and to facilitate fish species identification and abundance estimation through the water column. Second, we discuss a scattering model, inspired by Weston's work on arrays of air bubbles, which incorporates coherence and multiple scattering effects between swimbladders of comparable size to investigate the levels and fluctuations of scattering from fish schools. Third, we discuss an acoustic reference target, constructed from sheets of ''Bubble-Wrap®'' packaging material and successfully deployed and tested, which is a practical implementation of Weston's theory for the scattering response of planar arrays of identical bubbles. [Work supported by ONR.]

Invited Papers

3:00

1pAO7. Source levels of impulsive sound sources in underwater acoustics. N. Ross Chapman (School of Earth and Ocean Sci., Univ. of Victoria, P.O. Box 3055, Victoria, BC V8W 3P6, Canada)

Impulsive sound sources have been used extensively in underwater acoustics for many different research applications. Since the initial work by Weston in developing a simple analytical model for an underwater explosion, there have been several theoretical and experimental programs designed to determine source levels. More recently, other types of sources such as air guns and water guns have been introduced from marine seismic research, and there is renewed interest in knowing accurate source levels for assessing the impact on marine environments. In this paper the results of a series of experiments carried out to measure the source levels of several different types of impulsive sources are summarized. These included traditional 0.82-kg SUS charges, small and medium sized air guns from 5–185 cu. in., and a 160 cu. in. water gun. The SUS charges were exploded at shot depths from 18–200 m, and the air guns and water guns were fired at shallow depths from 1–5 m, corresponding to the conventional operating depths. The experiments provided high-quality shot waveforms that were processed to determine calibrated source levels in 1/3 octave frequency bands from 10–600 Hz. The measured values are compared to predictions from Weston's simple model.

3:20–3:35 Break

3:35

1pAO8. Frequency-dependent attenuation in unconsolidated marine sediments. Michael D. Richardson (Marine Geosciences Div., Naval Res. Lab, Stennis Space Center, MS 39529-5004, mike.richardson@nrlssc.navy.mil)

Wood and David Weston (1964) reported that *in situ* attenuation varied linearly with frequency (constant Q) over the frequency range 4 to 70 kHz in mud sediments from Emsworth Harbour, Hampshire UK. This linear frequency dependence seemed at odds with propagation models according to Wood and Weston. Since this pioneering work, actually conducted in 1951–52, numerous authors have measured attenuation in a variety of unconsolidated sediments and over a wide range of frequencies. Hamilton (1972, 1985), Kibblewhite (1989), and Bowles (1997) provide excellent compilations of frequency-dependent attenuation in unconsolidated sediments. Given the measurement difficulties, the wide variety of techniques used to measure attenuation, and changes in the nature of sediment at different spatial scales, the exact form of frequency dependence is still a widely debated issue. Recent measurements over the frequency range of 20–100 kHz in sandy sediments tend to support a linear dependency of attenuation with frequency, at least over this frequency range. [Work supported by ONR.]

Contributed Papers

3:55

1pAO9. Ten years of hydroacoustical observations of the behavior and distribution of small pelagic fish in the west coast of Baja California, Mexico. Carlos Robinson (Instituto de Ciencias del Mar y Limnologia, UNAM, Ciudad Universitaria, Mexico 04500, robmen@servidor.unam.mx)

The main goal is to present results on the behavior and distribution of small pelagic fish on the west coast of Baja California, Mexico using hydroacoustics and related to oceanographic parameters. From December 1993 to September 2002, 20 oceanographic surveys have been done off the west coast of Baja California, Mexico aboard the R/V ''El Puma.'' Two areas are covered, a Northern area from Punta Colnet to Punta Baja (30 54′, 116 40′ W to 29 26′ N 115 29′ W) and a Southern area from Punta Eugenia to Bahia Tortugas (27 29′ N 115 22′ W to 26 47′ N 113 55′ W). Results show that since 1993 echo-counting has been reduced significantly in both areas. Results are discussed in terms of oceanographic parameters and the presence of the 1997 El Niño. Before the 1997 El Niño, echo-counting was high in both areas. The behavior is reversed during El Niño. However, in the central area results from March 2000 may suggest a possible change in this tendency.

4:10

1pAO10. Measuring acoustic backscattering of deepwater fish *in situ* using a manned submersible. Kelly Benoit-Bird, Whitlow Au (Hawaii Inst. of Marine Biol., P.O. Box 1106, Kailua, HI 96734), Christopher Kelley, and Christopher Taylor (Univ. of Hawaii at Manoa, Honolulu, HI 96822)

An outstanding problem in fisheries acoustics is the depth dependence of scattering characteristics, required for sonar surveys, of swimbladder-bearing fish. The swimbladder, which is the major source of acoustic reflectivity, may become compressed due to increasing pressure with water depth, changing backscatter characteristics. To address this, echoes from deepwater snappers were obtained from a manned submersible using broadband sonar. A low-light camera mounted next to the sonar transducer permitted simultaneous identification of species, fish size, and orientation. Data were compared to echoes from captured fish measured at the surface. The relationship between fish length and *in situ* target strength showed no difference from the relationship measured at the surface. No differences in the species-specific temporal echo characteristics were observed between surface and *in situ* measures. This indicates that the size and shape of the fish's swimbladder are maintained both at the surface and at depths of up to 250 m.

4:25

1pAO11. Broadband temporal and spectral structure of acoustic backscatter from Hawaiian Lutjanid snappers. Whitlow W. L. Au and Kelly J. Benoit-Bird (Hawaii Inst. of Marine Biol., P.O. Box 1106, Kailua, HI 96734)

The characteristics of acoustic echoes from six species of deep dwelling (up to 350 m) Hawaiian Lutjanid snappers were determined by backscatter measurements at the surface. A broadband linear frequency modulated signal and a short dolphin-like sonar signal were used as the incident signal. The fishes were anesthetized and attached to a monofilament net which was in turn attached to a rotor so echoes could be collected along the roll, tilt, and lateral axes. The echo waveforms were complex with many highlights and varied with the orientation of the fish. The highlight structure was determined by calculating the envelope of the cross-correlation function between the incident signal and the echoes. In the tilt plane, the strongest echo occurred when the incident angle was perpendicular to the long axis of the swim bladder. The number of highlights was the fewest at this perpendicular orientation and increased as the fish is tilted from this orientation. The echo structures were easily distinguishable between species and were generally consistent within species. The highlight structure of the echoes resulted in the transfer function being rippled, with local maxima and minima at different frequencies.

4:40

1pAO12. *In situ* acoustic estimates of the swimbladder volume of Atlantic herring, *Clupea harengus*. Redwood W. Nero, Charles H. Thompson (Naval Res. Lab., Stennis Space Center, MS 39529-5004), and J. Michael Jech (Northeast Fisheries Sci. Ctr., Woods Hole, MA 02543)

Most marine fish maintain swimbladder volumes equivalent to 4%–5% of their body weight in order to maintain neutral buoyancy. In many fish the addition or removal of gas from the swimbladder is accomplished with the gas gland, a blood invested portion of the swimbladder wall. However, several families, including the herring family, Clupeidae, lack a gas gland. Instead, these fish possess a pneumatic duct between the esophagus and the swimbladder by which they are believed to inflate their swimbladders by ''gulping'' atmospheric air at the sea surface. Acoustic measurements at 1.5–5 kHz on fish in the Gulf of Maine showed a swimbladder resonance peak near 2.3 kHz at 180 m depth. Midwater trawls confirmed that the fish were Atlantic herring (*Clupea harengus*) of 19–28 cm length. Calculations using a model of swimbladder resonance gives swimbladder volumes of 1.3% at 180 m. Extrapolation using Boyle's law suggests that at the sea surface, these herring would need to inflate their swimbladders by up to four times the volume required for neutral buoyancy. In general, swimbladders of the Clupeidae may resonate at lower frequencies than previously expected. [Work supported by ONR and NMFS.]

4:55

1pAO13. Fine-scale diel migration dynamics of an island-associated sound-scattering layer. Kelly Benoit-Bird and Whitlow Au (Hawaii Inst. of Marine Biol., P.O. Box 1106, Kailua, HI 96734)

The Hawaiian mesopelagic boundary community, an island-associated, midwater sound-scattering layer, undergoes diel vertical and horizontal migrations. To understand the dynamics of the community's migration at small temporal scales and large spatial scales, five bottom-mounted, 200-kHz active-acoustic mooring that transmitted ten signals every 15 min, from dusk until dawn for 5 days. Two layers within the boundary community were observed to undergo simultaneous diel vertical and horizontal migration. Vertical migration rates were measured at 0–1.7 m/min, while the horizontal rate averaged 1.67 km/h, swamping the vertical movement. The vertex of the migration pattern was observed 45 min before the midpoint between sunset and sunrise. Until the vertex, animal density increased relatively constantly as the animals migrated towards shore, with the highest animal densities found in the shallowest areas at midnight. Animal abundance estimates at the leading and trailing edge of the layer support the hypothesis that increased animal densities near shore are related to packing, as mesopelagic animals avoid the surface and the bottom. We observed high levels of biomass moving rapidly, over a great distance, into shallow waters very close to shore, providing insight into the significant link the mesopelagic boundary community provides between near-shore and oceanic systems.

5:10

1pAO14. Tidal matched field processing inversion for water depth and source range in the Intimate96 test. A. Tolstoy (ATolstoy Sci., 8610 Battailles Court, Annandale, VA 22003, atolstoy@ieee.org), S. Jesus, and O. Rodríguez (Univ. of Algarve, Faro, Portugal)

Examining Intimate96 hydrophone data (300 to 800 Hz) we see clearly the effects of tidal changes, i.e., of changing water depths. In this work we will examine Matched Field Processing (MFP) sensitivity at that range of frequencies to expected tidal changes (the depth varies ± 1.0 m from the nominal of 135 m). Is it possible to invert such data to accurately and uniquely estimate water depth D as a function of time (tides)? What about accurate, unique, *simultaneous* estimates of source range r_{sou}? What happens when we use multiple frequencies and when D is known to shift in a predictable fashion? Can the r_{sou} vs D ambiguity ever be resolved for a successful, unique MFP inversion for those parameters?

5:25

1pAO15. Influence of fetch limited surface roughness on mid-to-high frequency acoustic propagation in shallow water. Robert Heitsenrether, Mohsen Badiey (Ocean Acoust. Lab., College of Marine Studies, Univ. of Delaware, Newark, DE 19716, rheits@udel.edu), James Kirby (Ctr. for Appl. Coastal Res., Univ. of Delaware, Newark, DE 19716), and Steve Forsythe (Naval Undersea Warfare Ctr., Newport, RI 0234)

Surface waves are among several environmental parameters that can influence broadband mid-to-high frequency (1–18 kHz) acoustic wave propagation. Understanding the interaction of sound waves at a rough surface requires a detailed description of the ocean wave spectrum. In shallow water regions, due to proximity to land, surface waves are usually fetch and duration limited with reduced spectral level and higher frequency components. A model that approximates the wave spectra for a fetch limited sea has been combined with acoustic ray-based method for analysis of forward scattered acoustic signals in such a coastal environment. Numerical modeling is employed to investigate time-frequency-angle characteristics of ray paths reflected from a rough sea surface. Temporal variability of acoustic signal fluctuations has been examined as a function of varying sea surface. To validate this model, results are compared against a unique set of experimental data collected in a fetch limited region. The experimental design allowed an examination of time evolution of a single surface bounced ray path. Simultaneous wind speed and acoustic propagation measurements allowed correlation between the individual ray paths and the sea surface at varying sea state conditions. For low wind speed conditions, model results predict the temporal fluctuations of the measured acoustic signal propagation.

MONDAY AFTERNOON, 2 DECEMBER 2002 CORAL GARDEN 1, 1:00 TO 3:55 P.M.

Session 1pBB

Biomedical Ultrasound/Bioresponse to Vibration and Signal Processing in Acoustics: Acoustic Microscopy

Joie P. Jones, Chair
Radiological Sciences, University of California, Irvine, California 92697-5000

Invited Papers

1:00

1pBB1. A short history of acoustical microscopy. Joie Jones (Dept. of Radiol., Univ. of California, Irvine, Irvine, CA 92697-5000, jpjones@uci.edu)

Optical microscopy has a long and interesting history, going back thousands of years to discoveries made in both Assyrian and Mayan cultures. Acoustical microscopy, on the other hand, has had a much shorter but equally interesting history, going back only to the mid-20th century. This presentation traces the development of acoustical microscopy from its very beginnings to the present. Comparisons with other microscopic techniques will point out the unique features offered by acoustical microscopy. A wide range of application areas will be reviewed and future prospects and potentials discussed.

1:30

1pBB2. Scanning tomographic acoustic microscopy. Hua Lee (Dept. of Elec. & Computer Eng., Univ. of California, Santa Barbara, Santa Barbara, CA 93106, hualee@ece.ucsb.edu)

This paper provides an overview of the design and development of the scanning tomographic acoustic microscopy (STAM). This research effort spans over a period of more than 12 years, which successfully elevated the acoustic microscopy from the traditional intensity-mapping mode to the level of holographic and tomographic imaging. The tomographic imaging capability of STAM was developed on the platform of the scanning laser acoustic microscope (SLAM), which operates in a coherent transmission mode with plane-wave illumination and scanning laser wavefield detection. The image formation techniques were based on the backward propagation method implemented in the plane-to-plane format. In this paper, the key elements of the design and development, including the modification of the data-acquisition hardware, implementation of image reconstruction algorithms for multiple-frequency and multiple-angle tomography, and the high-precision phase-correction and image registration techniques for the superposition of coherent sub-images, will be discussed. Results of full-scale experiments will also be included to demonstrate the capability of holographic and tomographic image formation in microscopic scale.

2:00

1pBB3. Intravascular ultrasound: From the acoustic microscope into the catheterization laboratory. Antonius F. W. van der Steen, Chris L. de Korte, and Cornelis J. Slager (Thorax Ctr., Erasmus Medical Ctr., Ee 23.02, P.O. Box 1738, 3000 DR Rotterdam, The Netherlands, vandersteen@tch.fgg.eur.nl)

One of the explicit goals of acoustic microscopy (AM) of biological tissues is to gain information and insights *in vitro* that will improve clinically used diagnostic ultrasound. This lecture will focus on the transfer of knowledge on vascular ultrasound obtained from acoustic microcopy to interventional cardiology. Spectral AM has shown that calcified atherosclerosis can be discriminated from fibrous and fatty plaques. The discrimination between fibrous and fatty plaques is less pronounced, but AM has shown these have distinct different anisotropy properties. Furthermore, it has been shown *in vitro* that fibrous tissues have much higher Youngs moduli than fatty tissues. AM has also shown that endothelial cells are sensitive to shear stress. In the catheterization laboratory this knowledge plays an important role in vulnerable plaque detection. A vulnerable plaque is a nonobstructing plaque consisting of a fatty pool covered by a thin fibrous cap. Breaking of the cap annually kills 225 000 people in the USA. A combination of biplane angiography, 3D IVUS and computational fluid dynamics allows one to determine shear stress at the endothelium. This has proven to be a predictor for the long term outcome of interventions such as balloon angioplasty and (drug eluting) stent placement.

2:30–2:45 Break

2:45

1pBB4. Application of acoustic microscopy to assessment of cardiovascular biomechanics. Yoshifumi Saijo, Hidehiko Sasaki, Shin-ichi Nitta, Motonao Tanaka (Dept. of Medical Eng. & Cardiology, Inst. of Development, Aging and Cancer, Tohoku Univ., 4-1 Seiryomachi, Aoba-ku, Sendai 980-8575, Japan), Claus S. Joergensen, and Erling Falk (Aarhus Univ., 8000 Aarhus, Denmark)

Acoustic microscopy provides information on physical and mechanical properties of biological tissues, while optical microscopy with various staining techniques provides chemical properties. The biomechanics of tissues is especially important in cardiovascular system because its pathophysiology is closely related with mechanical stresses such as blood pressure or blood flow. A scanning acoustic microscope (SAM) system with tone-burst ultrasound in the frequency range of 100–200 MHz has been developed, and attenuation and sound speed of tissues have been measured. In human coronary arteries, attenuation and sound speed were high in calcification and collagen, while both values were low in smooth muscle and lipid. Another SAM system with 800-MHz–1.3-GHz ultrasound was applied for aortas of Apo-E deficient mouse, which is known to develop atherosclerosis. Attenuation of ultrasound was significantly higher in type 1 collagen compared to type 3 collagen. Recently, a new type FFT-SAM using a single-pulse, broadband frequency range ultrasound (20–150 MHz) has been developed. Cardiac allograft was observed by FFT-SAM and the acoustic properties were able to grade allograft rejection. SAM provides very useful information for assessing cardiovascular biomechanics and for understanding normal and abnormal images of clinical ultrasound.

3:15

1pBB5. Comparative study of optical detection for scanning laser acoustic microscopy. Moises Cywiak (Centro de Investigaciones en Optica, A.C., Apdo, Postal 1-948, 37000 Leon, GTO, Mexico) and Glen Wade (Univ. of California, Santa Barbara, CA 93106, wade@ece.ucsb.edu)

Scanning laser acoustic microscopy (SLAM) provides a way of visualizing and measuring surface features of nanometric order by a combination of acoustical and optical means. The acousto-optical interface in SLAM is an acoustically transparent and optically reflecting surface embedded in the acoustic medium. Acoustical excitation causes a dynamic surface deformation which is picked up by a focused scanning laser beam which, after reflection, is modulated in its phase and angle of reflection. There are three basically different demodulation schemes reported in the literature: the knife-edge detector, the time-delay interferometric detector, and the reference-beam detector. (In addition, a new detector derived from the knife-edge detector, namely the pyramidal-mirror detector, is scheduled for separate treatment in this session.) This paper presents comparative studies of the above three basic methods of detection. The performance characteristics of each are analyzed in detail by a careful examination of the transfer function for each of the systems. Computer simulations for their operation provide a comprehensive picture of the strengths and weaknesses of each.

3:35

1pBB6. Increasing image resolution using the pyramidal detector. Steve Isakson (Isakson Engineering, 8355 San Rafael Rd., Atascadero, CA 93422), Luis Roberto Sahagun (Centro de Investigaciones en Optica, A.C., Apdo. Postal I-948, 37000 Leon, GTO, Mexico), and Glen Wade (Univ. of California, Santa Barbara, CA 93106)

The knife-edge detector (KED) has been used in transverse wave, scanning laser acoustic microscopes (SLAM) successfully for many years. It possesses a good balance between spatial bandwidth, detector noise insensitivity, and detector grain stability. Many detectors have tried to increase the bandwidth to improve the image resolution, only to be difficult to use and susceptible to vibration and mechanical variations. The authors have invented and designed a pyramidal detector (PD) that combines the stability and noise insensitivity of the KED with a significantly improved bandwidth in both axes of the object plane. The detector uses the entire signal provided at the detector to increase the signal to noise ratio and significantly decrease the cover slip spatial frequencies that are difficult to detect. The increased bandwidth allows image resolution approaching what an ideal detector could achieve. Additionally, unlike the KED, the PD spatial bandwidth is approximately isotropic to waves traveling in the cover slip. Increased spatial resolution and uniformity result. This property is particularly useful for back-propagation in tomographic applications.

MONDAY AFTERNOON, 2 DECEMBER 2002 CORAL SEA 1 AND 2, 1:00 TO 3:15 P.M.

Session 1pMU

Musical Acoustics: Musical Instrument Acoustics

Uwe J. Hansen, Chair

Department of Physics, Indiana State University, Terre Haute, Indiana 47809

Contributed Papers

1:00

1pMU1. Shape optimization techniques for musical instrument design. Luis Henrique (Instituto Politecnico do Porto, Escola Superior de Musica e Artes do Espectaculo, R. da Alegria, 503, 4000-046 Porto, Portugal), Jose Antunes (Instituto Tecnologico e Nuclear, 2686 Sacavem Codex, Portugal), and Joao S. Carvalho (Universidade Nova de Lisboa, 1050-069 Lisboa, Portugal)

The design of musical instruments is still mostly based on empirical knowledge and costly experimentation. One interesting improvement is the shape optimization of resonating components, given a number of constraints (allowed parameter ranges, shape smoothness, etc.), so that vibrations occur at specified modal frequencies. Each admissible geometrical configuration generates an error between computed eigenfrequencies and the target set. Typically, error surfaces present many local minima, corresponding to suboptimal designs. This difficulty can be overcome using global optimization techniques, such as simulated annealing. However these methods are greedy, concerning the number of function evaluations required. Thus, the computational effort can be unacceptable if complex problems, such as bell optimization, are tackled. Those issues are addressed in this paper, and a method for improving optimization procedures is proposed. Instead of using the local geometric parameters as searched variables, the system geometry is modeled in terms of truncated series of orthogonal space-funcitons, and optimization is performed on their amplitude coefficients. Fourier series and orthogonal polynomials are typical such functions. This technique reduces considerably the number of searched variables, and has a potential for significant computational savings in complex problems. It is illustrated by optimizing the shapes of both current and uncommon marimba bars.

1:15

1pMU2. The acoustical Klein–Gordon equation: A time-independent perturbation analysis. Barbara J. Forbes (Dept. of Environ. and Mech. Eng., The Open Univ., Walton Hall, Milton Keynes MK7 6AA, UK)

The acoustical Klein–Gordon equation, describing one-dimensional wave propagation in a duct of varying cross-section, is discussed. Dispersive solutions, not elucidated by the Webster equation, are examined and perturbative geometric ''potentials'' are defined. A time-independent, first-order expression for the perturbed eigenfunctions—defined as the potential energy per unit length of duct—is derived. Eigenvalue shifts are defined in terms of a sinusoidal perturbative term, and Ehrenfest's theorem is used to obtain the first-order shifts in the duct resonances. It is found that the perturbation may be in or out of phase with the radiation pressure, thus strengthening or weakening the resonances, respectively; and that the perturbation may raise, lower, or have no effect on the resonance frequencies, depending on the interaction of the phases of the terms. The results are compared with the standard theory of pipe resonances, which assumes perturbations to the cross-section of the pipe rather than directly to the eigenvalues.

1:30

1pMU3. Holographic interferometry and finite element modeling of handbells. John R. Buschert (Goshen College, Goshen, IN 46526, johnrb@goshen.edu)

Holographic interferometry was used to map out the vibration modes of a C4 handbell. A finite element model (FEM) of the handbell was also created. The FEM program can be made to present its results in a graphic format which mimics the stripes seen in interferometry. Thus, the FEM model can easily be compared in detail to the holograms. Excellent agreement between the two has been obtained, which is evidence for the validity of the finite element model. The FEM has also been used to explore the effects of changing the shape of the bell. The effects on the overtone structure of changing the bell in some unusual ways will be presented.

1:45

1pMU4. Transverse and torsional modes of vibration of American organ reeds. Blake M. Dirksen (Loras College, Dubuque, IA 52004, dirkbm@loras.edu) and James P. Cottingham (Coe College, Cedar Rapids, IA 52402)

A reed from an American reed organ consists of a brass tongue riveted to a frame with an opening just large enough for the reed to pass through during the course of its oscillation. To a first approximation, the reed tongue can be modeled as a cantilever beam of uniform cross section, and the mode frequencies of transverse and torsional modes can be calculated. The reeds used in this study differ from this simple model in several ways, including a nonuniform thickness along the reed length. In addition, the reed includes a curved spoon-like section at the tip of the reed tongue as well as an asymmetric twist at the tip. Transverse and torsional modes of vibration of a mechanically excited reed tongue have been studied using a proximity sensor (variable impedance transducer), a laser vibrometer, and a TV holography system. The motion of the air-driven reed has also been investigated. Although the motion of air-driven reed is dominated by the first transverse mode, some evidence of higher-order transverse modes and torsional modes has been observed. [Work supported by the NSF from REU Grant No. 0139096.]

2:00

1pMU5. The influence of reed curvature on the tone quality of lingual organ pipes. G. R. Plitnik (Dept. of Phys., Frostburg State Univ., Frostburg, MD 21532, gplitnik@frostburg.edu) and J. Angster (Fraunhofer Institut fur Bauphysik, Stuttgart, Germany)

Given certain design constraints, such as the type of stop being voiced and the desired tone quality, reed voicers must use consummate skill to curve each tongue so as to produce the best and most stable tone, as well as maintaining a consistent tone quality across an entire rank of pipes. The curvature given to a reed tongue influences not only the harmonic structure of the steady-state sound, but also the attack. Two fundamentally different types of curvature are typically employed, the chorus reed (trompette) curve (which yields a bright sound) and the smooth-toned curve employed for solo reeds such as the clarinet. This study investigated the effect of reed curvature on the vibration and tone of reed tongues of both types. Two $F2$ pipes (a trompette and a clarinet) were constructed and voiced with 6 different tongues each to produce a variety of tones. The reed's vibration was measured under typical conditions by laser vibrometer; the pressure waves in the boot and in the shallot were measured by means of one-eighth inch microphones and the emitted sound was recorded at the egress. By performing various measurements simultaneously, phase differences were also determined.

2:15

1pMU6. The acoustics of the echo cornet. Robert W. Pyle, Jr. (11 Holworthy Pl., Cambridge, MA 02138, rpyle@post.harvard.edu) and Sabine K. Klaus (America's Shrine to Music Museum, Landrum, SC 29356)

The echo cornet was an instrument produced by a number of makers in several countries from about the middle of the nineteenth to the early twentieth centuries. It consists of an ordinary three-valve cornet to which a fourth valve has been added, downstream of the three normal valves. The extra valve diverts the airstream from the normal bell to an ''echo'' bell that gives a muted tone quality. Although the air column through the echo bell is typically 15 cm longer than the path through the normal bell, there is no appreciable change of playing pitch when the echo bell is in use. Acoustic input impedance and impulse response measurements and consideration of the standing-wave pattern within the echo bell show how this can be so. Acoustically, the echo bell is more closely related to handstopping on the French horn than to the mutes commonly used on the trumpet and cornet.

2:30

1pMU7. Significance of torsion modes in bowed-string dynamics. Octavio Inacio (Instituto Politecnico do Porto, Escola Superior de Musica e Artes do Espectaculo, R. Alegria, 503, 4000-046 Porto, Portugal), Jose Antunes (Instituto Tecnologico e Nuclear, 2686 Sacavem Codex, Portugal), and Luis Henrique (Instituto Politecnico do Porto, 4000-046 Porto, Portugal)

Several aspects of bowed-string dynamics are still inadequately clarified. The importance of torsion modes on the motion regimes is one such issue. Experiments involving torsion are difficult and most of the results available pertain to numerical simulations. The authors' approach differs from previous efforts in two main aspects: (1) the development of a computational method distinct from the wave-propagation approach pioneered by McIntyre, Schumacher, and Woodhouse and (2) an extensive and systematic analysis of the coupling between torsion and transverse motions is performed. The numerical simulations are based on a modal representation of the unconstrained string and a computational approach for friction that enables accurate representations of the stick-slip forces and of the string dynamics, in both time and space. Many relevant aspects of the bowed-string can be readily implemented, including string inharmonic behavior, finite bow-width, and torsion effects. Concerning the later aspect, a realistic range of the torsional to transverse wave-speed ratio is investigated, for several values of the bow velocity and normal force. Results suggest that torsion modes can effect both transient durations and steady state regimes, in particular when the above-mentioned ratio is <4. Gut strings should then be particularly prone to torsion effects.

2:45

1pMU8. The acoustics of the bagana. Stephanie Weisser (Aspirant FNRS-Laboratoire de Phonolgie, Univ. Libre de Bruxelles, Ave. F. Roosevelt, 50 CP 175, B 1050, Brussels, Belgium, stephanieweisser@swing) and Didier Demolin (Univ. Libre de Bruxelles, Brussels, Belgium)

The bagana is a big Ethiopian lyre with ten strings. The instrument is found in the area of the Amhara, the culturally dominant tribe of Ethiopia. It is an intimate instrument, played only with the voice, for prayer and meditation. It can be tuned in two pentatonic scales, and can be plucked with the fingers, string by string or with a plectrum, all strings together. The box of the bagana is made of wood covered with leather, and the strings are made of gut. They are very thick and between them and the bridge, there are ten buzzers. Therefore, the bagana produces a very deep and buzzing sound. The paper will analyze the acoustical function of several parts of this instrument, e.g., the sound box and its crosslike hole at the back. The influence of the buzzers on the fundamental frequency, the spectrum, the duration, and the intensity of the signal will be closely examined. The role of the five unused strings (the ''rest'' strings) will also be examined.

3:00

1pMU9. Acoustic characteristics of Ekonda scrapers. Didier Demolin and Stephanie Weisser (Free Univ. of Brussels, 50 av. F. D. Roosevelt, 1050 Brussels, Belgium)

This paper describes some acoustic characteristics of a musical instrument played with the complex vocal polyphonies of the Ekonda of the Congo. The complexity of these songs and the remarkable pitch accuracy of their intonation are striking given that there is no tuning fork or fixed pitch instrument which can account for the pitch stability. Ekonda scrapers are required to accompany the polyphonies. An acoustic study of these idiophones was made to understand their contributions to the songs. The scrapers are made in a hollow piece of a palm tree branch. The instrument is played by rubbing a piece of hard wood upon splits made on the piece of palm tree. In addition to the friction noise due to the rubbing of the piece of hard wood, there are some very distinct resonances which can be identified. An important observation is that there is always a very intense resonance at the frequency of the musical scales tonic. The relation between the pitch of the tonic and the frequency of the scrapers resonances which act as a tuning fork are detailed.

Session 1pNS

Noise: Environmental Noise Planning and Legislation

Lawrence S. Finegold, Cochair
Finegold & So, 1167 Bournemouth Court, Centerville, Ohio 45459-2647

Eugenio Collados, Cochair
Depto. de Fisica, Universidad de Santiago de Chile, Santiago, Chile

Chair's Introduction—1:00

Invited Paper

1:05

1pNS1. Development of a model local noise ordinance standard. Lawrence S. Finegold (Finegold & So, Community & Environ. Noise Consultants, 1167 Bournemouth Ct., Centerville, OH 45459, lsfinegold@earthlink.net) and Bennett M. Brooks (Brooks Acoust. Corp., Vernon, CT 06066)

A comprehensive, easy to understand and enforceable local noise ordinance can be a powerful tool in the effort to manage the noise environment at the community level. At the present time, however, many communities do not have a local noise ordinance, and those that do exist can vary considerably. In order to provide guidance to government officials involved in the development of noise ordinances, the American National Standards Institute (ANSI) Standards Committee on Noise (S12), Working Group 41 is developing a Model Local Noise Ordinance. Although this effort is still in the early conceptual stages, this paper will describe some of the issues and approaches that are being considered in the development of this document. It is envisioned that Part 1 of this possible new ANSI Standard will address general community noise control issues that should be considered in the development of a noise ordinance and Part 2 will provide a sample noise ordinance with a menu of standardized language sections that can be selected to fit individual community situations. Ranges of recommended noise exposure criteria will be provided, along with a brief discussion of issues that local officials should consider in choosing these criteria.

Contributed Papers

1:30

1pNS2. Railroads, noise and the city: A manual for authorities. Fernando J. Elizondo-Garza, Cesar A. Leal-Chapa, Miguel Cupich-Rodriguez, and Jorge Cupich-Guerrero (Acoust. Lab., FIME, Univ. A. de Nuevo Leon, P.O. Box 28 "F," Cd. Universitaria, San Nicolas, 66450, N.L., Mexico, fjelizon@ccr.dsi.uanl.mx)

Trains crossing cities produce different problems and annoyances; one of them is noise, which directly affects the neighborhoods near the railroad tracks. This situation must be solved jointly by the city authorities and the railroad companies in two ways: planning, which looks to avoid future problems, and short-term solutions, which have the objective to control the present problems. In this paper a manual for authorities is presented that gives an overview of the available options that help in the decision-making process necessary to achieve a problem-free interaction between railroads and cities in relation to noise.

1:45

1pNS3. Conflicting noise ordinances in a metropolitan city. Allan K. Kennedy (Environ. Health and Safety Services, Black & Veatch Corp., 11401 Lamar Ave., Overland Park, KS 66211)

Controlling community noise has become an important aspect in most communities. The desire to provide an environment that is acceptable and peaceful to residents and conducive to businesses sometimes creates conflicts in the regulatory requirements. This conflict is compounded in metropolitan cities where many communities are adjacent. Each community has a set of priorities for its citizens directing how ordinances are written and what sound limits are permitted on certain land uses. Noise ordinances in a United States metropolitan area with a population of 1.5 million were reviewed for their similarity and dissimilarity with respect to zoning. It was discovered that even though the communities share the same borders, they have vastly different noise limits in terms of amplitude, time of day, required parameter (Leq, Ldn, etc.), and land use. The conflicts arise for noise sources that are located at the borders of these cities.

2:00

1pNS4. The potential application of auditory neuroscience to improving the quality of environmental noise standards. George A. Luz (U.S. Army Ctr. for Health Promotion and Preventive Medicine, 5158 Blackhawk Rd., Aberdeen Proving Ground, MD 21010) and John G. Neuhoff (The College of Wooster, Wooster, OH 44691)

In the Public Policy for Noise session at ASA's last meeting, Fidell stated that U.S. environmental noise regulations are hampered by (1) treating people as if they had a sound level meter in their brain and (2) overreliance on the Schultz curve. This paper looks at four stages in replacing the SLM in the brain: (1) Pre-1980 when knowledge of psychoacoustics exceeded the capability of instruments (Case study: U.S. Environmental Protection Agency's 1974 decision to use A-weighting instead of a loudness-based measure). (2) The 1980s when instrumentation could imitate psychoacoustics (Case study: Development of the loudness meter). (3) The 1990s when psychoacoustic research had relatively little influence on American noise standards (Case study: The decision of ANSI S12.9 to reject a Japanese proposal for assessing the annoyance of impulsive sounds [Ogura *et al.*, J. Noise Control Eng. **40**, 231–240 (1993)] in favor of a subjective "impulsive" and "highly impulsive" dichotomy). (4) Present opportunities for creative teamwork between equipment developers, standards writers, psychoacousticians, and neuroscientists (Case study: Explaining the U.S. Air Force's correction to the Sound Exposure Level for the added annoyance of low level, fast moving jet aircraft by "auditory looming").

2:15

1pNS5. Comparison between procedures of previsions in sound propagation in a quarry. Emanuele Sarri and Guido Alfaro Degan (Dept. of Mech. Eng., Roma Tre Univ., 79 Via Della Vasca Navale, Roma 00146, Italy)

The aim of this work is to compare the accuracy of numerical previsions of sound propagation in a quarry obtained with different algorithms. A comparison is made between the ISO 9613-1/2:1993 (E) standard for outdoor sound propagation, a new simplified algorithm based on the ISO code, a pyramid beam tracing method, and experimental measurements. The ISO 9613 standard proposes a detailed and complex method taking into account air absorption. It also takes into account the effects caused by the propagation over soil with varying properties, shielding both from thin and thick obstacles as well as the effects of vegetation layers and excess attenuation. The new algorithm simplifies ISO codes proposing an easy method, specific for a quarry. Pyramid beam tracing, implemented in Ramsete sound propagation software, is typically used to simulate sound fields in large rooms and also outdoors. Experimental and simulated data were used to built graphic plots, enabling a direct comparison of the results.

2:30

1pNS6. Assessment of adequacy of ray acoustics approach for prediction of barrier insertion loss in the presence of a reflecting ground. Daniel F. P. Pazos, Ricardo E. Musafir (Dept. of Mech. Eng./COPPE, Universidade Federal do Rio de Janeiro C.P. 68503, 21945-970 Rio de Janeiro, Brazil), and Eldad J. Avital (Univ. of London, London E1 4NS, UK)

The precision of insertion loss prediction obtained by applying Kurze–Anderson formula to each of the four possible ray paths connecting source and observer in the presence of a reflecting ground, and computing interference appropriately, is discussed. To this end, the field behind the barrier, given by the method described, is compared to that obtained by solving numerically the continuity and momentum equations simultaneously, using the appropriate boundary conditions to account for the perfectly reflecting ground and the barrier. Analysis of the agreement of the interference patterns obtained in both cases, for pure tones and for octave bands, permits determining the range in which the much simpler ray method provides sufficient results. Calculations with the Kurze–Anderson formula are performed with Mathematica 4.0, while the numerical propagation code is written in Fortran.

2:45

1pNS7. Investigation of the acoustic parameters that influence traffic noise. Alejandro A. Armas and Federico M. Iasi (Laboratorio de Acustica y Luminotecnia, Cmno. Centenario y 506-Gonnet (CP1897), Buenos Aires, Argentina)

Here, we analyze the behavior of the acoustic parameters L_{eq}, L1, L10, L50, L90, L99, L_{min}, and L_{max} of vehicular noise, which were measured in controlled laboratory conditions, for various traffic noise simulations. For that, sound recordings were created of equal duration but different composition, based on real recordings of the passage of different types of vehicles (cars, motorbikes, trucks, and buses) and using pink noise as background noise. This study is based on the necessity of finding the most appropriate parameters for the characterization of the traffic noise in the cities. The study began with the test of a measurement methodology that uses the equivalent continuous sound level, the main acoustical parameter applied in the city of La Plata, Argentina. However, L_{eq} was shown insufficient and inadequate in certain situations, especially those that didn't exhibit intense traffic noise, as found in certain residential areas. (To be presented in Spanish.)

3:00–3:15 **Break**

3:15

1pNS8. Measurement protocol for normalized noise maps. Gabriel Viro, Francisco Ruffa, Daniel Gavinowich, Oscar Bonello (Laboratorio de Acustica y Electroacustica, FIUBA, Paseo Colon 850, Buenos Aires, Argentina, laceac_uba@yahoo.com), Pablo Ciccarella, and Erica Barkasz (FIUBA, Paseo Colon 850, Buenos Aires, Argentina)

As cities grow bigger, traffic noise gets worse. In order to help in the determination of noisy areas, the LACEAC prepared a measurement protocol to aid in this task. This protocol is the base for a recommendation to the cities' governments. To put together this protocol, the LACEAC has analyzed different legislation together with measurements taken in several pilot areas of the city of Buenos Aires and determined the best approach based on the cultural habits of the city inhabitants. This protocol thus recommends the way that measurement locations should be determined, exposure time, the way to take the measurements, to study the results and to draw the noise maps.

3:30

1pNS9. Spectral information in noise-mapping: An exploratory study. Vivian Pasch, Patricia Mosconi, Marta Yanitelli, Susana Cabanellas, Jorge Vazquez, Juan C. Rall (Grupo Ruido, Fac. de Arquitectura, Natl. Univ. of Rosario, Riobamba 220 bis, 2000 Rosario, Argentina), and Federico Miyara (Natl. Univ. of Rosario, 2000 Rosario, Argentina, fmiyara@fceia.unr.edu.ar)

International standards such as ISO 1996 and ISO 717 as well as noise regulations in several countries are increasingly relying on spectral information in order to assess the acoustical behavior of materials and structures and the effects of noise on people. Nevertheless, the new European Union Directive on the assessment and management of environmental noise reinforces the A-weighted equivalent level (with appropriate night and evening corrections) as the preferred indicator for noise mapping. Considering that noise maps are a powerful zoning and planning resource, the idea of reporting the mean spectrum of noise at each selected location at different times is proposed and thoroughly justified. Arguments in favor of its feasibility are given, showing that, in spite of the widespread opinion, costs and required time may be reduced considerably by the use of low-priced, new-technology auxiliary equipment. Then an exploratory study is reported, in which (a) the spectrum of traffic noise in Rosario (Argentina) is compared with the internationally standardized traffic noise spectrum, and (b) the noise spectrum at an open street is compared with the noise spectrum at a street with a U-profile owing to the same vehicles.

3:45

1pNS10. Evaluation of urban railways noise impact. Massimo Coppi and Stefano Grignaffini (Dept. of "Fisica Tecnica," Univ. of Rome "La Sapienza"—Via Eudossiana, 18-00184 Rome, Italy)

The study of the environmental impact of urban railways mainly regards the noise generated by trains. Italian standards provide for the characterization of territorial pertinence zones (from the outer center line and for each side of the railway tracks), inside which specific absolute limit values of noise introduction produced by the same infrastructure are permitted. Therefore, according to provisions in these areas, the noise evaluation has to be performed referring only to the infrastructure contribution, without evaluating other acoustic sources in the same areas. As a consequence, in the pertinence zones the imposed limits for the infrastructure presence and the limits imposed by the acoustic municipal zoning, taking into account the acoustic impact of the other sources, are valid simultaneously but separately when evaluating the acoustic impact. However, in these areas the general acoustic climate is due to the overlap of both acoustic classes, and the noise induced on the population is determined by the contemporary presence of both sources. It is eventually very important to evaluate the effective noise dose absorbed by the population, especially when having to design mitigation interventions.

4:00

1pNS11. Study of noise external to public hospitals in the metropolitan area of Guadalajara. Martha Orozco, Javier Garcia, Gabriela Hernandez (IMACH, Departamento de Ciencias Ambientales, CUCBA, Universidad de Guadalajara, Km 15 1/2 Carr. a Nogales, Las Agujas Zapopan, Jalisco, Mexico), Arturo Figueroa, Jorge Macias (Direccion de Ecologia, H. Ayuntamiento de Guadalajara, Guadalajara, Jalisco, Mexico), Alan Delgadillo (Secretaria de Educacion, Guadalajara, Jalisco, Mexico), Esmeralda Vazquez, and Maria del Carmen Rivera (Universidad de Guadalajara, Las Agugas, Zapopan, Jalisco)

Environmental noise is at the present time a cause of concern, for the serious nuisance that it causes, and also the effects on health and behavior of individuals, on human activities, as well as for the psychological and social consequences. Hospital centers are places where numerous factors of quality and degradation can affect the recovery of patients. Knowing the acoustical conditions in some of the main hospitals of the city will make it possible to suggest measures to assist the present problem. We sampled 7 hospitals. The measurement points were selected at corners and at representative points or areas of pedestrian and vehicular entrance, a minimum of 4 points per block. We detected critical points of environmental noise in the vicinity of the hospitals, that require urgent attention. Some of the critical levels of noise were for LEQ, 93.4 and averages of this around 84.63 and maximum levels of 114.2, caused by an ambulance siren.

4:15

1pNS12. Effects of meteorology on predicted levels of aircraft noise. Kenneth Plotkin, Bruce Ikelheimer (Wyle Laboratories, 2001 Jefferson Davis Hwy., Ste. 701, Arlington, VA 22202, kplotkin@wylelabs.com), Jerome Huber, and John-Paul Clarke (MIT, Cambridge, MA 02139)

Calculation of average noise (e.g., Ldn) around airports generally ignores the effects of atmospheric gradients as these effects are assumed to average out over the course of a year. The validity of this assumption was tested through a numerical study using the aircraft noise simulation model NMSIM. Specifically, NMSIM was extended to account for three-dimensional refraction by wind and temperature gradients, plus refraction and scattering into shadow zones, as well as ground impedance effect. Five years of meteorological data at a number of airport locations was obtained, and divided into hourly conditions. A nominal airport, based on a major air carrier airport, was defined. NMSIM was run for hourly operations and weather conditions at each airport location. The resultant Ldn contours were compared to each other by season and location, and also to contours computed for the baseline assumption of no gradients. [Work supported by NASA Langley Research Center.]

4:30

1pNS13. Military aircraft noise and nonlinear acoustics. Victor W. Sparrow, Kent L. Gee (Grad. Prog. in Acoust., Penn State, 316B Leonhard Bldg., University Park, PA 16802, vws1@psu.edu), J. Micah Downing, and Kenneth J. Plotkin (Wyle Laboratories, Arlington, VA 22202)

A new joint program between Wyle Laboratories, Penn State, and others has been initiated to develop a better noise model for military fighter aircraft. As is well known, the high sound amplitudes produced by modern jets imply the importance of nonlinear effects in the sound propagation. In the literature one can find several experiments clearly showing spectral broadening and the development and coalescence of shocks as the noise propagates with distance. Current U.S. DoD noise models, nevertheless, neglect nonlinear distortion. A number of different nonlinear propagation predictions schemes are available, and currently there is no broad consensus as to which models work best for jet noise. This talk will discuss the applicability of several of these methods to the current need. Only when nonlinear propagation methods have been coded and tested against laboratory and full scale measurements will a predictive tool be available for assessing the environmental noise impacts of modern aircraft. [Work supported by SERDP.]

MONDAY AFTERNOON, 2 DECEMBER 2002 — CORAL ISLAND 1 AND 2, 1:00 TO 4:30 P.M.

Session 1pPA

Physical Acoustics: Atmospheric Acoustics and Impedance Surfaces

Craig J. Hickey, Cochair
National Center for Physical Acoustics, University of Mississippi, Coliseum Drive, University, Mississippi 38677

Rodolfo Martinez, Cochair
CIIDIR, IPN, Oaxaca, Mexico

Contributed Papers

1:00

1pPA1. Effects of nonlinearity on the propagation of acoustic pulses in random media. Robin Cleveland (Dept. of Aerosp. and Mech. Eng., Boston Univ., Boston, MA 02215, robinc@bu.edu), Laurent Dallois (Oxford Univ., Oxford OX1 3LB, UK), and Philippe Blanc-Benon (LMFA UMR CNRS 5509, 69131 Ecully Cedex, France)

We conducted a numerical investigation into the propagation of finite-amplitude pulses in media with inhomogeneous random sound speed. An *N* wave (idealized sonic boom) was used as the pulse shape. Initial simulations considered a medium with a single spherical scattering object with a slow sound speed. This object acted as a focusing lens. As the amplitude of the *N* wave was increased nonlinear effects initially led to enhancement of focusing, reduction in shock risetime, and a shift of the peak away from the object. However, for high amplitude, energy loss at the shock led to a dramatic reduction in the amplitude of the focus and a shift towards the object. Simulations were then carried out in a two-dimensional random media. The sound speed in the random media was constructed using a Fourier mode decomposition with parameters appropriate for turbulence in the atmospheric boundary layer. For low amplitude waves the *N* wave was focused and defocused by regions of low and high sound speed, respectively. However, the presence of multiple paths means that the wave form no longer resembled an *N*-wave after propagating about 10 wavelengths. As the amplitude was increased the focusing was enhanced and more localized.

1:15

1pPA2. Effect of turbulence on the risetime of sonic booms and spark generated *N* waves. Bart Lipkens (Mech. Eng. Dept., Western New England College, 1215 Wilbraham Rd., Springfield, MA 01119) and Philippe Blanc-Benon (LMFA UMR CNRS 5509, 69134 Ecully Cedex, France)

The risetime of acoustic pulses, such as sonic booms and electric spark generated N waves, is affected by propagation through turbulence. Risetime increases with increasing propagation distance and turbulence intensity. Data from electric spark propagation through turbulence show that Pierce's wave front folding theory (1971) correctly describes the dependence of risetime τ on propagation distance x, i.e., $\tau \propto x^{11/7}$, and turbulence kinetic energy dissipation rate ϵ, i.e., $\tau \propto \epsilon^{4/7}$. More recently, Pierce (AIAA-95-105) also derived a dispersion relation for acoustic pulse propagation through turbulence. The dispersion relation leads to an extra term in the propagation equation and takes into account the averaged contribution of all or part of the turbulence spectrum. A review of the dispersion theory is presented. Then a Van Kármán turbulent kinetic energy spectrum is used to obtain an accurate representation of both very large and very small turbulence structures. New results are compared with previous results obtained with a Kolmogorov spectrum.

1:30

1pPA3. Scattering of sound by a penetrable sphere above a plane boundary. Wai Keung Lui and Kai Ming Li (Dept. of Mech. Eng., The Hong Kong Polytechnic Univ., Hung Hom, Kowloon, Hong Kong, mekellui@polyu.edu.hk)

The problem of acoustic scattering by a penetrable sphere irradiated by a point source is investigated. A theoretical model is developed for the case of scattering by a sphere placed above an acoustically hard and an impedance boundary. The sphere is made of an extended reaction material that is assumed to be acoustically penetrable. The problems are tackled by using the technique of variables separation and appropriate wave field expansions. By adopting an image source method, the solutions can be formulated in form of multiscattering interaction between the sphere and the image sphere near a hard and an impedance boundary. The effect of boundary impedance on the reflected sound fields is incorporated in the numerical model by using the well-known Wely–van der Pol formula. Preliminary indoor measurements are conducted in an anechoic chamber for the characterization of the acoustical properties of the penetrable sphere as well as the impedance boundary. A further set of experimental measurements is carried out to demonstrate the validity of the proposed theoretical models for various receiver locations around the sphere above the impedance boundary. [Work sponsored by the Innovation & Technology Commission, MTR Corp. Ltd., and The Hong Kong Polytechnic University under Project No. ZM07.]

1:45

1pPA4. Narrow-band pulse propagation in a one-dimensional stratified random medium. Shimshon Frankenthal and Mark J. Beran (Faculty of Eng., Tel Aviv Univ., Ramat Aviv, Israel)

In the stratified random medium considered here, the spatially fluctuating wave speed and refractivity vary only in the range direction, which is normal to the planes of stratification. To treat backscattering in such a medium, it is convenient to split the field into forward- and backward-propagating components, and derive coupled equations that govern the range evolution of the statistical moments of these components. The derivation entails an ensemble-averaging operation, which is here predicated on the key assumption that the two components, which are incident from opposite directions on a differential range slab, are statistically independent of the refractivity fluctuations within that slab. The assumption is justifiable when the fluctuations exhibit a sufficiently rapid time dependence. This procedure is used to derive equations for the bichromatic coherence of the two field components, which are then solved to determine the evolution of the power flux associated with the propagation of a signal due to a planar narrow-band pulse incident on a semi-infinite scattering slab. It is shown that the pulse signal is attenuated exponentially in the range direction, on the so-called "localization" scale, while the scattered power forms echo pulses which are gradually attenuated until all the incident pulse energy is reflected back out of the slab.

2:00

1pPA5. Nonlinear acoustics—Coupling between hydrodynamic and acoustic pressure fields. Mauricio Pazini Brandao (IEAv-CTA Rodovia dos Tamoios km 5,5, Sao Jose dos Campos, SP, Brazil, 12228-840)

Linear or Classical Acoustics considers that sound waves propagate essentially without any medium movement. However, in Aeroacoustics we deal with phenomena where there are the simultaneous generation and propagation of sound in a moving medium. Unless the flow velocity is very low, when in aerodynamics the fluid can be modeled as being incompressible, nonlinearities must be taken into account to better model the flow physics. In this paper, by considering the exact mass and momentum equations in the form of a generalized Ffowcs–Williams and Hawkings equation, the coupling between the hydrodynamic and acoustic pressure fields generated by the motion of a solid body in still air is studied. The extent of the validity of linear hypotheses and decoupling between the two pressure fields is discussed. Strategies to consider the coupling for faster movements are indicated. This coupling appears in computations as stepwise linear iterations between the hydrodynamic and acoustic perturbation pressure fields. The goal of this research is to devise a mathematical and computational model where the formation of normal shock waves in transonic flows appears as a nonlinear interaction process between aerodynamics and aeroacoustics.

2:15

1pPA6. Velocity measurements in the acoustic oscillatory boundary layer with laser Doppler anemometry. J. R. Castrejón-Pita, A. A. Castrejón-Pita, and G. Huelsz (Centro de Investigación en Energía, UNAM, A.P. 34, 62580 Mexico, Mor. Mexico)

Velocity measurements using laser Doppler anemometry (LDA) in the oscillatory viscous boundary layer (OVBL) produced by acoustic waves are presented. The amplitude velocity profile of acoustic standing waves in air with frequencies of 68.5, 114.5, and 343.5 Hz are reported. The results agree with the predictions of linear theories and show that the small discrepancies found in similar measurements made with hot wire anemometry (HWA) [Huelsz *et al.*, Exp. Fluids **32**, 612 (2002)] are due to the interaction of the hot wire probe with the flow and the wall. The advantages and disadvantages of the LDA technique compared with HWA are discussed for OVBL measurements. [Work supported by CONACyT Project No. 32707-U. The authors wish to thank Guillermo Hernández for his valuable technical support.]

2:30–2:45 Break

2:45

1pPA7. Effective impedance of hard rough surfaces. Keith Attenborough and Patrice Boulanger (Dept. of Eng., Univ. of Hull, Hull HU6 7RX, UK)

The effective impedance of hard rough surfaces insonified from a point source has been investigated through boss models, boundary element simulations, and measurements. The complex excess attenuation measured or predicted has been fitted for effective impedance by means of a formulation for the sound field above a smooth finite impedance plane. It has been found that the effective impedance plane is higher than the nominal one and that the results are very sensitive to the location of the specular reflection point. Polynomial expressions for the real and imaginary parts of the effective impedance have been derived for various types of roughnesses.

3:00

1pPA8. A high-order on-surface radiation condition for computing scattering from concave objects and extended surfaces. David C. Calvo (U.S. Naval Res. Lab., Washington, DC 20375)

Approximate solutions to scattering problems can be obtained efficiently using on-surface radiation conditions (OSRCs). An OSRC may be viewed as an approximation of the exact nonlocal (integral) Dirichlet-to-Neumann operator, and therefore requires less effort to compute surface quantities and far-field patterns in comparison with other methods. In a previous study [Calvo *et al.*, IEEE Trans. Antennas Propag. (in press)], a higher-order OSRC was developed for two-dimensional convex scatterers that was accurate for large scattering angles relative to the surface normal and moderate surface curvatures. A remarkable result was the exceptional accuracy obtained for end-on incidence with hard scatterers—a challenging case in which creeping waves arise and past OSRCs have had difficulty treating. In this talk, improvements to the OSRC are discussed by relaxing the convexity restriction to allow for compact objects with moderately deep concavity with favorable results. The OSRC is then applied to scattering by extended pressure-release surfaces featuring moderately deep corrugations. Results are favorable in comparison with other more costly numerical techniques. A particular advantage of the high-order OSRC occurs for grazing angles of incidence where the effects of shadowing come into play. Possible applications to ocean acoustics and microwave remote sensing of the sea surface will be addressed.

3:15

1pPA9. Experimental and numerical study of air-coupled surface waves generated above strips of finite impedance. Wenhao Zhu, Gilles A. Daigle, and Michael R. Stinson (Inst. for Microstructural Sci., Natl. Res. Council, Ottawa, ON K1A 0R6, Canada)

A surface composed of a lattice of small cavities can support the propagation of air-coupled surface waves. Energy is localized near the surface and, since the sound pressure near the surface can be greater than if the surface was rigid, passive amplification is obtained. By restricting the lattice of cavities to a strip of finite width embedded in an otherwise rigid surface, the amplification depends on the direction of the incident sound. Thus directional receivers can be designed. These directional receivers can provide more amplification than would be obtained with a semi-infinite lattice of cavities. In this paper, we will discuss various ways in which strips of finite impedance can be configured to enhance the amplification (and directivity) properties of surface waves. Experiments were carried out on a model surface and the measurements are compared with numerical results obtained using a boundary element method.

3:30

1pPA10. Sound propagation in a refracting atmosphere above an impedance discontinuity. Shahram Taherzadeh and Nick Harrop (Dept. of Environ. & Mech. Eng., The Open Univ., Milton Keynes MK7 6AA, UK)

de Jongs formulation of sound propagation above a ground with a single impedance change has been extended to include effects of a refracting atmosphere and atmospheric turbulence. The theory is compared with a numerical algorithm based on a hybrid Boundary Integral Equation/Fast Field Program developed for predicting the propagation of sound in a refracting atmosphere above an uneven, discontinuous terrain. By using the analogy of sound diffraction over curved surfaces to atmospheric refraction over flat ground surfaces, the effect of temperature and wind velocity gradients in the presence of flat ground surfaces can be studied. Measurements of the excess attenuation of sound from a point source over a mixed impedance curved surface are carried out in an anechoic chamber as well as outdoor measurements over a tarmac–grass discontinuity. These measurements are compared with predictions based on the extended de Jong theory and the hybrid BIE/FFP algorithm in the nonturbulent case. Results show that where there is a single discontinuity between acoustically hard and finite impedance surfaces both models are found to give satisfactory agreement with measured data except when the discontinuity is midway between the source and the detector.

3:45

1pPA11. Method of designing layered sound absorbing materials. Youssef Atalla and Raymond Panneton (Acoust. and Vib. Group, Univ. of Sherbrooke, 2500 Boul. de l'Universit Sherbrooke, QC J1K 2R1, Canada, yatalla@gme.usherb.ca)

A widely used model for describing sound propagation in porous materials is the Johnson–Champoux–Allard model. This rigid frame model is based on five geometrical properties of the porous medium: resistivity, porosity, tortuosity, and viscous and thermal characteristic lengths. Using this model and with the knowledge of such properties for different absorbing materials, the design of a multiple layered system can be optimized efficiently and rapidly. The overall impedance of the layered systems can be calculated by the repeated application of single layer impedance equation. The knowledge of the properties of the materials involved in the layered system and their physical meaning, allows to perform by computer a systematic evaluation of potential layer combinations rather than do it experimentally which is time consuming and always not efficient. The final design of layered materials can then be confirmed by suitable measurements. A method of designing the overall acoustic absorption of multiple layered porous materials is presented. Some aspects based on the material properties, for designing a flat layered absorbing system are considered. Good agreement between measured and computed sound absorption coefficients has been obtained for the studied configurations. [Work supported by N.S.E.R.C. Canada, F.C.A.R. Quebec, and Bombardier Aerospace.]

4:00

1pPA12. The interaction of airborne sound with the poroelastic ground. Craig J. Hickey and James M. Sabatier (Natl. Ctr. for Physical Acoust., Univ. of Mississippi, University, MS 38655, chickey@olemiss.edu)

An airborne acoustic wave impinging on the surface of the ground provides a good vibrational source for investigating the near surface. Research has been carried out on the use of this type of source for landmine detection, characterization of agricultural soils, and studying the characteristics of snow and ice cover. Since the ground and snow is porous, the impinging sound wave induces motion of the fluid within the pores as well as vibrating the solid framework. Vibrating the solid component of the ground using an airborne sound source is known in the acoustic community as acoustic-to-seismic (a/s) coupling. The most complete understanding of the interaction of airborne sound with the ground is to treat the ground as a poroelastic or poroviscoelastic medium. This treatment predicts three types of waves can propagate in a bulk homogeneous porous material with a deformable framework: two dilatational waves and one rotational wave. The dilatational waves are usually referred to as the fast, or Type I, and slow, or Type II, waves and deform both the solid and fluid constituents. This presentation will discuss the energy partition and impedance at an air-porous medium interface as related to the solid and fluid deformations.

4:15

1pPA13. Acoustical measurement system to improve agricultural implements for soil protection. Rodolfo Martinez and F. Diego (CIIDIR, IPN, Oaxaca, Mexico, rodolfo_mc@yahoo.com)

This research work is based on theoretical mechanics and agricultural mechanics theory applied to the study of the behavior of animal-pulled implements for seeding or harvesting for minimizing erosion of soil. For this purpose the pertinent acoustic measurements are presented with the objective of finding acoustical parameters useful to evaluate different designs of these kinds of implements with regard to depth and shape of the earth moving device in order to protect agriculture soil from erosion.

Session 1pSAa

Structural Acoustics and Vibration: Complex Structures and Fluid Loading

Peter H. Rogers, Chair
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Contributed Papers

1:00

1pSAa1. Vibration of submerged prolate spheroidal shells with internal fluid loading. Jeffrey E. Boisvert (Naval Undersea Warfare Ctr., Newport, RI 02841, boisvertje@npt.nuwc.navy.mil) and Sabih I. Hayek (Penn State Univ., University Park, PA 16802)

The equations of motion for nonaxisymmetric vibration of submerged prolate spheroidal shells of constant thickness with internal fluid loading were derived using Hamiltons principle. The shell theory used in this derivation includes shear deformations and rotatory inertias. The shell displacements and rotations were expanded in infinite series of comparison functions. These include associated Legendre functions in terms of the prolate spheroidal angular coordinate and circular functions in the azimuthal angle coordinate. The external and internal fluid loading impedances were computed using expansions of prolate spheroidal wave functions in each domain. The shell was excited by axisymmetric normal surface forces, including a point load at the shell apex and ring load at other locations. Numerical results were obtained for the driving and transfer mobilities for several shell thickness-to-half-length ratios ranging from 0.005 to 0.1, and for various shape parameters, a, ranging from an elongated spheroid shell ($a=1.01$) to a spherical shell ($a=100$). Results are presented for various combinations of external and internal fluid loading, and comparisons are made to the *in vacuo* shell vibration. [Work supported by ONR and the Navy/ASEE Summer Faculty Program.]

1:15

1pSAa2. Noise radiated from a rotating submerged elastic cylindrical thin shell. Jayme J. Caspall, Minami Yoda, and Peter H. Rogers (The George W. Woodruff School of Mech. Eng., Georgia Inst. of Technol., Atlanta, GA 30332)

Although the aeroacoustics of high Reynolds number boundary layers is reasonably well understood, less is known about the hydroacoustics of such flows, and the effect of fluid loading. The noise generated by the turbulent boundary layer around an elastic, thin-walled and cylindrical shell rotating in quiescent water was studied in the Georgia Tech. Underwater Acoustic Tank for Reynolds numbers up to 200 000. The steel shell, which is filled with air, has a diameter D of 0.625 m, a wall thickness of $0.004D$, and an aspect ratio of unity; the tank dimensions are $19D$ by $12D$ by $11D$. Extraneous noise sources (e.g., bearing and motor vibration) were isolated from the net signal to estimate flow noise. Radiated noise power was calculated from hydrophone data under a diffuse field assumption. To our knowledge, these results are unique in both their structural acoustics and fluid mechanics scaling.

1:30

1pSAa3. Vibration of a cylindrical membrane shell subjected to a steady rotational load. Arthur I. Koral and Mauro Pierucci (San Diego State Univ., San Diego, CA 92182-3108, mpierucci@engineering.sdsu.edu)

The vibration of a cylindrical membrane shell is driven by a point source moving along its circumferential direction. The point source is modeled by a Dirac delta function. The shell vibration is governed by the membrane equations. No variation is assumed to take place along the shell axial direction. The coupled partial differential equations for the radial and the tangential displacements $w(\text{theta},t)$ and $v(\text{theta},t)$ are decoupled by decomposition and two sets of coupled ordinary differential equations for the time varying magnitudes of the shell circumferential modes are obtained. The force starts its motion at $t=0$ and continues at a constant rate omega. The spectrum of the shell vibration, as expected, shows frequencies that are multiples of the rotating forcing frequency, multiples of the propagating wave front frequency as well as other components. For large times these spectra yield vibrations resembling those of broadband noise.

1:45

1pSAa4. Flexural waves on narrow plates. Andrew Norris (Dept. of Mech. & Aerosp. Eng., Rutgers Univ., Piscataway, NJ 08854-0909)

Flexural wave speeds on beams or plates depend upon the bending stiffnesses, which differ by a well-known factor depending on the Poisson's ratio. A quantitative analysis of a plate of finite lateral width displays the plate-to-beam transition, and permits asymptotic analysis that shows the dependence on the width. Orthotropic plates are analyzed using both the Kirchhoff and Kirchhoff–Rayleigh theories, and isotropic plates are considered for Mindlin's theory with and without rotational inertia. A frequency dependent Young's modulus for beams or strips of finite width is suggested, although the form of the correction to the modulus is not unique and depends on the theory used. The sign of the correction for the Kirchhoff theory is opposite to that for the Mindlin theory. These results indicate that the different plate and beam theories can produce quite distinct behavior. This divergence in predictions is further illustrated by comparison of the speeds for antisymmetric flexural modes on narrow plates. The four classical theories predict limiting wave speeds as the plate width vanishes, but the values are different in each case. The deviations can be understood in terms of torsion and how each theory attempts, or fails, to approximate this effect.

2:00

1pSAa5. Analysis of variable-thickness, streamlined transducer array windowing concepts for high speed underwater vehicles. Robert M. Koch (Adv. Technol. Div., Naval Undersea Warfare Ctr., Code 8232, Bldg. 1302, 1176 Howell St., Newport, RI 02841, kochrm@npt.nuwc.navy.mil)

Recent research in very high speed underwater vehicles shows they require a much more streamlined vehicle nose than the present rather flat tactical scale vehicle nose. It has been found that the common forward-facing transducer array with a constant thickness array window utilized on current lower speed vehicles is inadequate. Two newer alternate front-end array concepts suitable for lower drag, higher speed vehicles being investigated are (a) a variable thickness, streamlined array window on a flat forward facing array and (b) a streamlined vehicle nose structure consisting of a built-in distributed, conformal array. While these highly streamlined concepts are attractive from the standpoint of reducing vehicle drag at higher speeds, both require reexamination of the effects of high curvature on front-end sonar array performance. In the present paper, both above streamlined array concepts are numerically examined using the SARA2D dynamic structural-acoustic Finite Element Analysis (FEA) code. First, the acoustic performance of a hemispherical array window is compared to a common equal aperture flat window in both transmit (outgoing

acoustic wave) and receive (incident acoustic wave) modes. Second, a dynamic simulation of acoustic array beam-forming and beam-steering is performed for a conical shaped conformal array to assess the feasibility of the concept.

2:15

1pSAa6. Modeling of wall-pressure fluctuation based on time-mean flow field. Yu-Tai Lee, William Blake, Theodore Farabee, Michael Tse, and Joseph Brown (Naval Surface Warfare Ctr., Carderock Div., 9500 MacArthur Blvd., West Bethesda, MD 20817)

Time-mean flow field and turbulent flow characteristics from solving the Navier–Stokes equations are used to predict the flow direction wave number spectrum of wall-pressure fluctuations. The vertical turbulent velocity is represented by the kinetic energy contained in the local turbulent flow. A redistribution of the turbulent kinetic energy to account for the anisotropic turbulence is implemented based on the equilibrium turbulent shear flow. The spectral correlation model in predicting the wall-pressure fluctuation is obtained through the Green's function formulation, and the streamwise and spanwise wave number spectrum modelings. Predictions for the equilibrium flow agree well with measurements, and reveal an overlap region of an inverse of the frequency. Predictions for a 2-D reattached flow field after flow separation and a 3-D flow field on an airfoil with focus on the trailing edge and airfoil tip are discussed and compared to measurements. [Work supported by ONR.]

MONDAY AFTERNOON, 2 DECEMBER 2002 — CORAL GALLERY 1, 2:45 TO 4:30 P.M.

Session 1pSAb

Structural Acoustics and Vibration: Analytical and Numerical Methods

Rolando Menchaca, Chair
Av. Juan de Dios Batiz S/N, Col. Lindavista, D.P. C.P. 07070, Mexico

Contributed Papers

2:45

1pSAb1. A hybrid finite-element formulation for analyzing systems of beams and plates in the midfrequency range. Sang-Bum Hong and Nickolas Vlahopoulos (Dept. of Naval Architecture and Marine Eng., Univ. of Michigan, 2600 Draper Rd., Ann Arbor, MI 48109-2145)

A hybrid finite-element analysis (hybrid FEA) formulation has been developed in the past for computing the midfrequency vibration of systems that contain one type of energy. The hybrid FEA is based on characterizing as long members in a system all the members that contain a large number of wavelengths within their dimension. All the remaining members are considered as short. The Energy Finite-Element Analysis (EFEA) is employed for modeling the behavior of the long members, while the conventional FEA method is utilized for modeling the short members. In this paper the hybrid FEA formulation is extended to plate structures that are spot-welded to a frame comprised by tubular members. The new formulation is validated by comparing the hybrid FEA solution to results produced by very dense conventional FEA models in the mid-frequency range. [Research supported by the Automotive Research Center, US. Army.]

3:00

1pSAb2. Petrov–Galerkin's method hybrid with finite element into the Helmholtz equation solution. Part I. Itzala Rabadan Malda (Academia de acustica, ICE, ESIME, IPN, Mexico, D. F.), Emigdio Salazar Cordero (ESFM, IPN, Mexico, D. F.), and Jose Angel Ortega Herrera (SEPI, ESIME, IPN, Mexico, D. F.)

In this first part, this paper's purpose is to determine a numerical algorithm according to certain advantages that both Petrov–Galerkins and finite element method offer to resolve the wave equation completely, for simple geometry domains like circular and rectangular membranes, cones and cylinders, and parabolic and spherical volumes. It will permit to contemplate the Helmholtz equations reduced case. Then it can consider real domains like membranes, cones, cylinders, pipes, and parabolic and spherical volumes, polymaterial or discontinuous (with holes will be treated in a second part). This will allow determination of important design parameters for different acoustic devices.

3:15

1pSAb3. Petrov–Galerkin's method hybrid with finite element into the Helmholtz equation solution. Part II. Itzala Rabadan Malda (Academia de Acustica, ESIME, IPN, Mexico, D. F.), Emigdio Salazar Cordero (ESFM, IPN, Mexico, D. F.), and Jose Angel Ortega Herrera (IPN, SEPI, ESIME, Zacatenco, Mexico, D. F.)

This work proposes a hybridization between Petrov–Galerkins numeric method and finite element method (FEM) to resolve Helmholtz equation when dominion is an open or semiopen tube-shaped configuration and with determinate number of holes over cylindrical surface. It's pretended to solve these kind of cavities, thereby it allows us to obtain very important design parameters like: cavity length, quantity, size and distance between toneholes, form and size of mouthpiece or outlet. These parameters are design basis into acoustic and musical instrumentation: baffles outlet pipes, diffusers, silencers, flutes, oboes, saxophones, trumpets, quenas, and many more. In this way it's expected to determine advantages of this numeric method above another using actually.

3:30

1pSAb4. Simulation of the transient behavior of impact machinery using finite elements package ANSYS. Jose de Jesus Villalobos-Luna, Pedro Lopez-Cruz, Patricia Gonzalez-Guajardo, and Fernando J. Elizondo-Garza (Vib. Lab., FIME, Univ A. de Nuevo Leon, P.O. Box 28 "*F*," Cd. Universitaria, San Nicolas, 66450, N.L., Mexico, villalobosluna@hotmail.com)

In this paper the finite elements method is used to simulate the transient behavior of impact machinery and its foundation. Using the software package ANSYS, two cases are modeled: first, the impact machine directly mounted on the floor, and second, the machine mounted over an inertia block foundation. The results of the modeling permit clear visualization of transient vibrations in the machine and how they are transmitted to the foundation and the floor. How to use this modeling for didactic purposes is discussed.

3:45

1pSAb5. Nonstationary bifurcations with additive noise. Huw G. Davies (Univ. of New Brunswick, Fredericton, NB E3B 5A3, Canada, davies@unb.ca)

The response of nonlinear systems with slow variation of a parameter through a bifurcation may be critically affected by very-low-level noise. Examples to be discussed include passage through resonance of a periodically pumped laser, a transcritical bifurcation associated with a coupled pitch/roll model of ship motion, and a period-doubling cascade of a discrete map. In each case the original form of the response persists as the control parameter varies through the bifurcation, even though this original form is now unstable. Noise is required to trigger the bifurcated form; then there is a rapid transition with exponential growth from one form of response to another. Sinusoidal parameter variation through the bifurcation at sufficiently high frequency may effectively stabilize the original form by preventing an appreciable growth of the bifurcated form; noise is destabilizing. The two competing effects are analyzed using matched-asymptotic-expansions. The innermost of a nested set of three expansions describes how noise causes the growth of the bifurcating form from the original unstable form. Previous results for period-doubling [H. G. Davies and K. Rangavajhula, Proc R. Soc. London, Ser. A **457**, 2965–2982 (2001)] are modified for the other types of bifurcation, and are extended to a higher order period-doubling cascade using renormalization.

4:00

1pSAb6. Transient modeling of Lamb waves emitted by integrated transducers using a hybrid finite element–normal mode expansion technique. Laurent Duquenne, Emmanuel Moulin, Jamal Assaad, and Christophe Delebarre (Le Mont Houy, 59313 Valenciennes, Cedex 9, France, laurent.duquenne@univ-valenciennes.fr)

For a few years, the concept of integrated health monitoring of aeronautic structures has become an important issue. A promising solution is the emission of ultrasonic Lamb waves using thin piezoelectric transducers integrated to the structure. Indeed Lamb waves are known to be able to propagate over long distance and to interact with inner structural defects. One important aspect when applying Lamb waves to health monitoring is the control and optimization of their generation. Therefore, a hybrid finite element–normal mode expansion modeling technique adapted to piezoelectric transducers has been recently developed. This technique allows the determination of the amplitude of each Lamb mode as a function of the transducer parameters. So far, it had been successfully applied to the case of harmonic excitation only. In this paper, adaptation of this hybrid technique to transient excitation is presented, which enables to simulate actual experimental conditions. Contrary to other techniques presented in the literature, the present technique allows to take into account the actual electromechanical behavior of the integrated transducer. Predicted results have been successfully compared to experimental measurements performed on different types of materials.

4:15

1pSAb7. Sound radiation of a discontinuous structure calculated with various semianalytical and numerical methods. Berndt Zeitler and Michael Möser (Institut für Technische Akustik, Sekr. TA 7, Einsteinufer 25, 10587 Berlin, Germany)

The subject of investigation is an infinitely long radiator with the cross section of a pie slice. The modal radiation efficiency and directivity pattern are calculated for given normal velocity on the surface; rigid legs are assumed. Three semianalytical methods and one numerical method are used. The Wave-Approach (WA) splits the field into two regions assuming different wave types in each. Their amplitudes are chosen to fulfill the surface boundary conditions and to ensure a smooth transition between the regions. The Multi-Point–Multipole-Approach (MPMA), as the name suggests, uses several multipoles scattered within the structure, whose amplitudes are chosen such that the reconstructed normal velocity on the surface ideally equals the original. In this study the order is limited; only one mono- and two perpendicular dipoles are used. No restriction of order is made in the Single-Point–Multipole-Approach (SPMA), but of course one of quantity. For the Finite-Element-Method (FEM) Sommerfeld's radiation condition was chosen as the outer boundary condition. The results for different criteria and under certain circumstances are compared and discussed. The sound radiation is also visualized through animations displaying particle movement.

MONDAY AFTERNOON, 2 DECEMBER 2002 — GRAND CORAL 3, 1:30 TO 4:00 P.M.

Session 1pSC

Speech Communication: Speech Perception and Production by Hearing Impaired Individuals

Mario A. Svirsky, Cochair
Department of Otolaryngology, Head and Neck Surgery, Indiana University School of Medicine, Indianapolis, Indiana 46202

Jorge Gurlekian, Cochair
Laboratorio de Investigaciones Sensoriales, CONICET-UBA, Marcelo T. de Alvear 2202, 1122 Buenos Aires, Argentina

Chair's Introduction—1:30

Invited Papers

1:35

1pSC1. Language-specific, hearing-related changes in vowel spaces: A study of English- and Spanish-speaking cochlear implant users. Joseph Perkell (Speech Commun. Group, Res. Lab. of Electron., MIT, Cambridge, MA 02139), Marek Polak, Thomas Balkany (Univ. of Miami Med. School, Miami, FL), Jennell Vick, Harlan Lane, Ellen Stockmann, Mark Tiede, and Majid Zandipour (MIT, Cambridge, MA 02139)

This study investigates the role of hearing in vowel productions of postlingually deafened cochlear implant (CI) users. Based on the hypothesis that competing demands of intelligibility and economy of effort influence vowel production, we predicted that speakers of a language with a more crowded vowel space, such as American English, would show an increase in average vowel spacing (AVS

the average inter-vowel distance in the F1-F2 plane) with the provision of hearing from a CI; whereas speakers of a language with fewer vowels, such as Spanish, would not. Results of a preliminary on–off study supported the hypothesis: with hearing from a CI, 7 English-speaking CI users all increased AVS; however, among 7 Spanish speakers, some increased AVS and some reduced it. The current study is exploring these findings further with new groups of CI users and normal-hearing speakers of English and Spanish and an elaborated paradigm that includes different speaking rates and comparisons between pre-implant and post-implant recordings. Preliminary results will be reported. [Work supported by NIH.]

2:00

1pSC2. Computational models of vowel identification by English- and Spanish-speaking cochlear implant users. Mario A. Svirsky, Daniel C. Hadley, Heidi S. Neuburger, Su-Wooi Teoh (Dept. of Otolaryngol.-HNS, Indiana Univ. School of Medicine, Indianapolis, IN 46202), and Eloy Villasuso (Univ. of Miami, Miami, FL)

Cochlear implant (CI) users achieve significant levels of speech recognition on average, but cross-listener variability is very high. Unfortunately, our understanding of the speech perception mechanisms employed by CI users is still incomplete. To address this issue we have developed the multidimensional phoneme identification (MPI) model, which aims to predict phoneme identification for individual cochlear implant users based on their discrimination along specified acoustic dimensions. The MPI model was used to fit vowel confusion matrices from English- and Spanish-speaking CI users. Good agreement between predicted and observed matrices was obtained for both English and Spanish. Some of the acoustic dimensions required to obtain these fits were the same for both languages (e.g., $F1$ and $F2$), but others were not (e.g., $F3$ is required to obtain a good fit in English, but not in Spanish). These results are consistent with differences in the acoustic phonetics of the two languages: a low value of $F3$ is used in English to encode the retroflex vowel /r/, and this sound does not exist in Spanish. These results raise the possibility that the optimal stimulation strategies may differ across languages. [Work supported by NIDCD (R01-DC03937), NOHR, DRF, and BID/CONICYT (Uruguay).]

2:25

1pSC3. Use of the Spanish adaptation of the phonetic and phonologic Ling tests to evaluate progress in children with cochlear implants and hearing aids. Gonzalo Corvera, Maria Cristina Manrique, Juan Pablo Manrique, and Valeria Lapilover (Clinica Lomas Altas, Paseo de la Reforma 2608-9, Mexico D.F. 11950, Mexico)

The decision of when to implant a prelingually deafened child is based on his or her progress with hearing aids. It comes down to a subjective decision regarding whether the child could do better with an implant or not, is heavily influenced by the therapists' experience with cochlear implants, and is difficult to transmit objectively to new teams. The speech discrimination tests usually used tend to use words or phrases in and out of context scenario. Dr. Daniel Ling's phonetic and phonologic tests (1990) include aspects on auditory abilities, language comprehension, and articulation, and are evaluated in the course of therapy and not in a special evaluatory session. The Spanish adaptation of these tests (adapted by Dr. Ling in collaboration with Santiago Manrique and Cristina de Manrique, 1996) were used for this study, analyzing the results in children with cochlear implants and with hearing aids, to explore their use (or lack of it) as an adjunct for the prescription of a cochlear implant.

2:50–3:10 Break

3:10

1pSC4. Development of an Argentine Spanish hearing impaired speakers database. Jorge A. Gurlekian (Lab. de Investigaciones Sensoriales, CONICET-UBA, Marcelo T. de Alvear 2202, (1122) Buenos Aires, Argentina, jag@fmed.uba.ar) and Ana Sanchez Navarro (Centro de Medicina Física y Rehabilitación, (1058) Buenos Aires, Argentina)

Argentine Spanish hearing impaired speech has not been systematically registered or studied. A database with standardized methods for data collection and labeling is presented here. Speech of 600 speakers, adults, and children, with different types of hearing losses is recorded at 44100 Hz and 16 bits. The corpus consists of word lists, grouped by tonality and frequency of use, and five short sentences, containing all the phonemes and allophones. Semi-spontaneous speech, consisting of a description of two sets of simple pictures, is also recorded. Data are acoustically analyzed and labeled at the segmental—graphemic, phonetic and acoustic tiers—and suprasegmental levels, using a labeling method that incorporates psychoacoustic information into a combination of categorical and continuous descriptions of fundamental frequency. Syntactic labels are added to semi-spontaneous speech data. Labeled files are loaded into a relational SQL database to allow different types of queries. A complementary database provides information about personal and medical data, and results of hearing tests. These databases contribute to the description of acoustic-phonetic features of deaf speech, a comparison between speech perception and production, and new approaches for the adjustment of auditory prostheses. [Work supported by FONCYT, CONICET and Mutualidad Argentina de HipoacB4usicos.]

3:35

1pSC5. Cortical reponses to electrical stimulation from cochlear implants. Emily A. Tobey, Michael D. Devous, Sr., and Peter S. Roland (Univ. of Texas at Dallas, 1966 Inwood Rd., Dallas, TX 75235)

In order to examine factors contributing to speech perception performance variations in cochlear implant users, single photon emission computed tomography (SPECT) was used to examine cortical activity elicited by the electrical stimulation of multichannel cochlear implants. Subjects watched a 15-min videotaped story under several conditions: (a) audio presented monaurally in the aided right or left ears; (b) audio presented binaurally with aids; (c) a visual-only presentation; and (d) signals processed through the implant. Five minutes after the start of each story, 99mTc HMPAO was injected over 30 s to insure subjects were unaware of the tracer administration. Right and left monaural stimulation in normal-hearing subjects resulted in significant bilateral activation of Brodmann areas 41, 42, 22, 21, and 38. Despite similar hearing losses to each ear, significant differences in per-operative auditory cortex activation was observed between ears across the subjects. Post-implant, individuals with relatively high levels of open-set speech perception demonstrated bilateral activation of cortex; however, the extent of activation was significantly less than that observed for normal-hearing individuals. Individuals with minimal open-set speech perception scores demonstrated unilateral activation of the cortex on the hemisphere contralateral to the ear of implantation. [Work supported by NIH.]

MONDAY AFTERNOON, 2 DECEMBER 2002 GRAND CORAL 1, 1:00 TO 5:30 P.M.

Session 1pUW

Underwater Acoustics: Localization and Inversion Issues

Monica Montanari, Cochair
Department of Ocean Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139

Te-Chih Liu, Cochair
Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139

Contributed Papers

1:00

1pUW1. Rapid inversion of waveguide environmental parameters using an analytic adjoint method. Aaron Thode (Marine Physical Lab., Scripps Inst. of Oceanogr., La Jolla, CA 92093)

A method is presented for inverting sound-speed perturbations in a stratified waveguide environment over several kilometers range. An adjoint Green's function formalism is used to backpropagate the difference between a measured and modeled received field through the modeled waveguide environment, in a manner reminiscent of acoustic time-reversal methods. Using a set of linearized equations similar in form to the Born approximation, the backpropagated error field is converted into an estimate of an error surface gradient, or Frechet derivative [S. J. Norton, J. Acoust. Soc. Am. **106**, 2653–2660]. The gradient can then be used to locate the error surface minimum via a series of iterations. The use of a normal-mode waveguide Green's function enables a considerable analytic simplification of the equations. The similarities and differences between the adjoint approach, matched-field processing, and diffraction tomography are discussed. [Work sponsored by ONR.]

1:15

1pUW2. Beam-based matched field steering for large volumetric arrays. Henry Cox and Kevin D. Heaney (ORINCON Industries, 4350 N. Fairfax Dr., Ste. 470, Arlington, VA 22203)

A new approach is introduced to significantly improve the efficiency of generation of matched field steering vectors for large volumetric arrays. For a volumetric array it is shown that there is a virtual Equivalent Vertical Line Array (EVLA) with many fewer elements that captures all of the information contained in the acoustic propagation from a far field source to the receiving array. A relationship between the size of the virtual EVLA and the geometry of the volumetric array is derived. Element-based matched field steering vectors for the virtual EVLA can be computed in the usual way and then used to generate beam-based matched field steering vectors for shaded plane wave beams. By matching the mainlobes of the shaded plane wave beams of the virtual EVLA with the vertical beam pattern of the beams of the volumetric array, the beam-based steering vectors for the large real volumetric array are obtained without needing to compute its element-based steering vectors. For large volumetric arrays the savings can exceed an order of magnitude.

1:30

1pUW3. Characteristics of small boat acoustic signatures. Martin L. Barlett and Gary R. Wilson (Appl. Res. Labs., Univ. of Texas, P.O. Box 8029, Austin, TX 78713-8029, barlett@arlut.utexas.edu)

Small boats are often a dominant noise source in harbors, coastal regions, and lakes. However, detailed information about acoustic characteristics is not generally available. To remedy this deficiency, measurements of underwater acoustic signatures from various small boats have been conducted under controlled conditions. Boats used in the measurements were powered by a variety of gasoline and diesel motors in outboard, inboard–outboard, and inboard drive configurations. Measurements were made using a bottom mounted hydrophone in about 100 feet of water. In many instances, the boats were instrumented with a system that recorded the GPS position and engine RPM permitting accurate determinations of platform operating parameters. Measured small boat signatures contain both narrowband and broadband acoustic components. Narrowband components are generally associated with sources from the engine or drive. Narrowband levels in the observed spectra were found to exhibit significant variations and are believed to originate from fluctuations in the load on the engine and drive. Broadband energy was observed to be a dominant noise source at frequencies above several hundred Hertz and is a characteristic feature in all small boat signatures. Examples of small boat signatures will be presented and representative acoustic characteristics of this type of watercraft will be discussed.

1:45

1pUW4. A 3D forward-look sonar simulation model. Pierre-Philippe J. Beaujean, Julia Gazagnaire, and Joseph M. Cuschieri (Dept. of Ocean Eng., Florida Atlantic Univ., 101 N. Beach Rd., Dania Beach, FL 33004, pbeaujea@seatech.fau.edu)

A modeling tool for 3-D Forward-Look Sonar (3-D-FLS) or equivalent has been developed. The model replicates the entire process of a 3-D Forward-Look sonar generating a 3-D image of a target. The 3-D-FLS operates at a central frequency of 225 kHz and has a range of 100 m. The transmitted signal is a frequency-modulated chirp with 30 kHz of bandwidth. The source is a line array and the projector is a 64-element line array. Ray theory is used to calculate the trajectory of the rays. The model takes sound velocity profiles into account. The reverberation levels due to the sea bottom and sea surface are calculated using Kuos model. Targets of various shapes and sizes are modeled as a collection of reflecting data points. The target strengths of each point on a specific target are assumed equal. The final product is a modeling tool which can be used to define the

sonar hardware and processing software necessary to achieve various operational needs. Simulated results are validated using 3-D-FLS data collected during several at-sea experiments.

2:00

1pUW5. Autonomous underwater vehicle adaptive path planning for target classification. Joseph R. Edwards and Henrik Schmidt (Dept. of Ocean Eng., MIT, 77 Massachusetts Ave., Rm. 5-204, Cambridge, MA 02139)

Autonomous underwater vehicles (AUVs) are being rapidly developed to carry sensors into the sea in ways that have previously not been possible. The full use of the vehicles, however, is still not near realization due to lack of the true vehicle autonomy that is promised in the label (AUV). AUVs today primarily attempt to follow as closely as possible a preplanned trajectory. The key to increasing the autonomy of the AUV is to provide the vehicle with a means to make decisions based on its sensor receptions. The current work examines the use of active sonar returns from mine-like objects (MLOs) as a basis for sensor-based adaptive path planning, where the path planning objective is to discriminate between real mines and rocks. Once a target is detected in the mine hunting phase, the mine classification phase is initialized with a derivative cost function to emphasize signal differences and enhance classification capability. The AUV moves adaptively to minimize the cost function. The algorithm is verified using at-sea data derived from the joint MIT/SACLANTCEN GOATS experiments and advanced acoustic simulation using SEALAB. The mission oriented operating system (MOOS) real-time simulator is then used to test the onboard implementation of the algorithm.

2:15

1pUW6. Analysis of shallow water experimental acoustic bistatic data. Richard Brothers, Gary Heald, and Samantha Dugelay (QinetiQ, Newton's Rd., Weymouth DT4 8UR, UK, rbrothers@qinetiq.com)

During February 2002, data were collected in controlled experimental conditions in Weymouth Bay, UK. The experimental setup consists in a broadband source with variable depth and variable azimuthal and tilt angles and a 16 element receiver array located on a tower. The tower is placed at 27.4 m or 33 m from the source and the receiver is pointed in various directions for each pulse. Transmitted pulses consist mainly in CW and linear chirps with central frequencies at 150 kHz, bandwidths varying up to 100 kHz, and pulse lengths varying from 67 ms to 15 ms. The primary objectives of the data reported here are: (1) compare and validate the bistatic scattering strength model developed by the Applied Physics Laboratory of University of Washington; and (2) to assess the complexity and practical implementation of bistatic scattering for mine hunting purposes. Data are processed and the bistatic scattering strength is compared to the predicted bistatic scattering strength. Comparisons are discussed for various geometrical configurations and for different pulse types. Results show good concordance of the model and the experimental data despite ambient noise limitations due to difficult sea conditions.

2:30

1pUW7. Buried mine classification by means of higher-order spectral analysis. Monica Montanari and Henrik Schmidt (Dept. of Ocean Eng., MIT, 77 Massachusetts Ave., Rm. 5-204, Cambridge, MA 02139)

In the joint MIT/SACLANTCEN Generic Oceanographic Array Technology Sonar (GOATS) project, future missions are envisioned that employ one or more autonomous underwater vehicles (AUVs) for automated target detection and classification. The classification of buried mines after detection is important for reducing the false alarm rate of the mine hunting sonar system. Buried mine classification is pursued in this paper by employing higher-order spectral analysis. Due to the nature of the target, it is expected that there will be at least one elastic response following the specular return from the object. The elastic response is typically of very low signal to noise ratio, and the noise is correlated reverberation, so advanced spectral analysis must be employed to detect the elastic behavior of the target. Higher-order spectral analysis methods are applied to a time signal in a short temporal window following the specular return. The delay of the elastic return corresponds to the time necessary for the wave to travel around the perimeter of the object before it is reradiated toward the receiver. The effectiveness of this approach to mine/rock classification is shown by an application to at-sea data from the GOATS experiment series (1998, 2000, and 2002) as well as advanced acoustic simulations.

2:45

1pUW8. Deriving the spatial distribution and properties of radiating acoustic sources in a ship from a measurement of its signature in shallow water. Marshall V. Hall (DSTO Maritime Operations Div., 17 Pirrama Rd., Pyrmont, NSW 2009, Australia, Marshall.hall@dsto.defence.gov.au)

When a wideband point source passes a hydrophone in shallow water, the spectrogram of the signature shows a characteristic interference pattern. This pattern consists of a number of bands of strong signal, which decrease in frequency as the source approaches, and pass through minimum frequencies at the closest point of approach (CPA). If the environmental waveguide is range-independent the spectrogram is symmetric around the time of CPA. The geoacoustic model of the seabed is determined by using an optimization routine to match the computed with the measured spectrogram. For a hydrophone in the nearfield of a passing ship, the bands in the spectrogram are less clear, and are asymmetric even if the waveguide is range-independent. The objective is to represent a ship by a small number of point sources distributed in space, each of which has its own spectrum and effective directionality. The main source, the propeller, is directional in effect because the hull is an obstacle to transmission in the forward direction. For each source, the spectrum and directionality are expressed as functions of frequency and angle. The function coefficients are determined by using an optimization routine to match the computed with the measured signature.

3:00–3:15 Break

3:15

1pUW9. Concurrent detection and localization of buried targets using track-before-detect processing. Te-Chih Liu and Henrik Schmidt (MIT, Cambridge, MA 02139)

The GOATS (Generic Oceanographic Array Technology Systems) Joint Research Program explores the development of environmentally adaptive autonomous underwater vehicle (AUV) technology for Rapid Environment Assessment and Mine Counter Measurement (MCM) in coastal environments. MIT is developing the GOATS multistatic sonar concept which uses a low-frequency source on one AUV to subcritically insonify the seabed over a wide area, while a formation of multiple AUVs are used for mapping the associated 3-D scattered acoustic field in the water column. Exploring the different characteristics of the scattering from various buried targets, an algorithm has been developed for autonomous, concurrent detection and localization of buried targets. At the subcritical isonification angles necessary to sustain high coverage rate, the buried target detection depends on the measurement of very weak signals, in general undetectable by traditional detect-before-track algorithms. The method developed here applies a Track-Before-Detect (TBD) approach to solve this problem. This technique tracks the AUV trajectory first using the slowly changing environment information, and then the weak signal detection is declared after the AUV track is estimated at sufficient level of confidence. This new algorithm has been applied on the GOATS-2000 bistatic data. The result shows the successful navigation results by confident detection of three buried targets, two of which are particularly weak scatterers. A real-time, autonomous implementation of the algorithm was recently demonstrated in the GOATS-2002 experiment, and the result for both experiments will be discussed. [Work supported by ONR.]

3:30

1pUW10. Source motion effects on matched field processing. Katherine H. Kim and William S. Hodgkiss (Marine Physical Lab., Scripps Inst. of Oceanogr., La Jolla, CA 92093-0704, khkim@mpl.ucsd.edu)

Past matched field processing (MFP) analyses have typically overlooked the effects of source motion. However, in real-world applications of MFP, especially those involving the use of large arrays or in the highly dynamic shipping environments common to littoral waters, source motion can exacerbate the conflicting requirements of sufficient samples for adequate data covariance estimation and short-term stationarity assumptions. In the context of MFP, short-term stationarity can be assumed provided that the source does not traverse more than one beamwidth of the matched field processor. Thus, theoretically derived estimates of MFP resolution for a vertical line array are compared to those determined empirically from a shallow water acoustics experiment off the coast of San Diego. Predictions of the eigenvalue spreading that arises from source motion, based upon the work of Baggeroer and Cox [Baggeroer and Cox, Proc. of 1999 Asilomar Conference **1**, 103–108 (1999)], are then compared to experimental eigenspectra. Finally, the impact of interferer motion on adaptive MFP processor performance is presented.

3:45

1pUW11. Broadband matched-field tracking with horizontal line arrays in shallow water. Paul A. Baxley, Ahmad T. Abawi, and Randall Brannan (SPAWAR Systems Ctr., San Diego, Code 2857, 49575 Gate Rd., Rm. 170, San Diego, CA 92152-6435, baxley@spawar.navy.mil)

The use of three-dimensional matched-field processing to obtain time-dependent range, depth, and bearing estimates with a horizontal line array (HLA) can be computationally restrictive. The problem becomes much more tractable, however, when beam forming is first used to obtain bearing estimates versus time, which are then used to obtain range-depth ambiguity surfaces versus time. For the case of a moving source, matched-field tracking (MFT) compensates for source motion by integrating matched-field correlations over candidate source tracks through the bearing-range-depth space. The true track is determined by the highest integrated correlation, which also results in a gain in detectibility for the true source track. The effectiveness of this approach for the tracking of broadband sources in shallow water is studied via the analysis of HLA data collected during the Shallow Water Evaluation Cell Experiment 1996 (SWellEX-96), which occurred in 200 m water, 6 km southwest of San Diego. Broadband signals in this experiment included a narrowband comb and the broadband signature emanating from the source-tow ship. The MFT methoc can be used as a stand-alone tracker or as a tool to obtain initial track estimates for the initialization of a more efficient conventional tracker. [Work supported by ONR 321US.]

4:00

1pUW12. Identifying individual sources in matched-field processing by modifying the covariance matrix. Eric M. Giddens, Philippe Roux, and W. A. Kuperman (Marine Physical Lab., Scripps Inst. of Oceanogr., Univ. of California, San Diego, 8820 Shellback Way, La Jolla, CA 92093-0238)

A method for identifying multiple sources in matched-field processing (MFP) is proposed. The ambiguity surface produced by MFP may contain sidelobe structures that confound individual source identification. Data corresponding to the location of the loudest source is added to the signal and the dominant eigenvector of the covariance matrix is removed. The addition of data prevents the degenerate case where a single eigenvector describes multiple sources. The new MFP result has the source and its sidelobes removed from the ambiguity surface. The remaining sources can then be identified. This technique is applied to simulated data as well as Swell-Ex 96 data with a small number of snapshots. [Work supported by ONR.]

4:15

1pUW13. Sound from a light aircraft for underwater acoustic inversions. Eric M. Giddens, Fernando Simonet, Thomas R. Hahn, and Michael J. Buckingham (Marine Physical Lab., Scripps Inst. of Oceanogr., Univ. of California, San Diego, 8820 Shellback Way, La Jolla, CA 92093-0238)

Experiments are being conducted in shallow (30 m) water off La Jolla, CA, to investigate the potential usefulness of the sound from a single-engine, propeller-driven, light aircraft for performing underwater acoustic inversions. The sound signature of the aircraft contains harmonics between 50 Hz and 1 kHz, which return the low-frequency geoacoustic properties of the seabed. A microphone approximately 1 m above the surface monitors the sound in air, a seven-element vertical array detects the acoustic arrivals underwater and a single, buried hydrophone receives the signals in the sediment. Aircraft overflights have been made at altitudes between 33 m and 330 m, yielding the altitude-dependence of the peak levels received underwater. Using the vertical array, the reflection coefficient of the seabed is being measured as a function of grazing angle. From the reflection coefficient, the critical angle of the sea floor and hence the sound speed in the sediment are inferred. The sound speed in the sediment should also be available directly from the Doppler shift on the buried hydrophone. These techniques and the available data sets will be discussed in the presentation. [Work supported by ONR.]

4:30

1pUW14. An AUV underwater acoustic array. Gerald L. D'Spain, Paul A. Lepper, and Richard Zimmerman (Marine Physical Lab, Scripps Inst. of Oceanogr., La Jolla, CA 93940-0704)

An eight-element hydrophone array has been installed within the shroud of an Odyssey IIb AUV. Each array channel is digitized and recorded with 10-kHz bandwidth by an autonomous, PC-104+ data acquisition system. To determine the effects of the AUV body itself on the acoustic field measured by the array, tones at low (200–800 Hz) and mid- (2–8 kHz) frequencies were transmitted in a large water tank to the AUV by a source continuously varying in azimuth but fixed range. Bartlett beamforming for source azimuth using both plane wave replicas and replicas calculated using a 2-D time domain, finite-difference code that accounts for the scattering from the two glass spheres in the AUV shows that (1) not accounting for scattering results in 2- to 6-dB signal gain degradation, but (2) scattering moves the ambiguity surface sidelobes closer to the main lobe location, thus improving localization capability. The effect of scattering from the AUV on an azimuthally isotropic noise field, estimated by averaging over pings at all azimuths, is a decrease in spatial coherence at low frequencies over that in free space, thus increasing detection capability. [Work supported by ONR.]

4:45

1pUW15. Tabu optimization for matched field inversion. Zoi-Heleni Michalopoulou and Urmi Ghosh-Dastidar (Dept. of Mathematical Sci., New Jersey Inst. of Technol., Newark, NJ 07102, michalopoulo@adm.njit.edu)

Matched field processing is a powerful tool for source localization and geoacoustic inversion. Because of significant environmental and geometry uncertainties, however, matched field processing usually involves multiparameter searches. To facilitate these searches, global optimization techniques such as genetic algorithms and simulated annealing have been successfully employed. In this work, a different approach, tabu, is implemented for optimization in matched field inversion. Tabu is a technique relying on the use of memory; it searches for the global maximum of the objective function through a navigation process that avoids already revisited models, also making use of aspiration criteria and diversification for faster convergence. The tabu performance in localization and geoacoustic inversion is demonstrated through experimentation with both synthetic and real (SWellEX 96) data. The approach is shown to provide reliable estimates in an efficient manner. [Work supported by ONR.]

5:00

1pUW16. Determining low-frequency source location from acoustic phase measurements. Travis L. Poole (MIT/WHOI Joint Prog. in Oceanogr. and Oceanogr. Eng., Woods Hole Oceanogr. Inst., Woods Hole, MA 02543, tycho54@excite.com) and George V. Frisk (Woods Hole Oceanogr. Inst., Woods Hole, MA 02543)

For low-frequency cw sound sources in shallow water, the time rate-of-change of the measured acoustic phase is well approximated by the time rate-of-change of the source-receiver separation distance. An algorithm for determining a locus of possible source locations based on this idea has been developed. The locus has the general form of a hyperbola, which can be used to provide a bearing estimation at long ranges, and an estimate of source location at short ranges. The algorithm uses only acoustic phase data and receiver geometry as input, and can be used even when the source frequency is slightly unstable and/or imprecisely known. The algorithm has been applied to data from low-frequency experiments (20–300 Hz), both for stable and unstable source frequencies, and shown to perform well. [Work supported by ONR and WHOI Academic Programs Office.]

5:15

1pUW17. A simple method of passive source range measurement. Zeng Juan, Gao TianFu, Guo ShengMing, and Chen Yan (Inst. of Acoust., Chinese Acad. of Sci., Beijing 100080, PROC)

In this paper, a simple method of passive range measurement is discussed. The receiver system can be either hydrophone or horizontal array. Unlike earlier methods of passive source range measurement, we mainly consider the phase information of the passive source, rather than the amplitude. The method only uses the simplest principle range=velocity time. The key of the method is how to acquire the partial deviation of the phase with respect to radial frequency and measurement variables. In physics, the former is equal to time, which can be obtained from the spectrum of the source. The latter is equal to group velocity, which can be evaluated according to the environmental variable, such as water depth, sound profiles, bottom quality, etc. In fact, measurement variables can be substituted by the sound speed in water over the bottom; the error is no more than 8 percent.

MONDAY EVENING, 2 DECEMBER 2002 — CORAL ISLAND 1 AND 2, 7:00 TO 9:00 P.M.

Session 1eID

Interdisciplinary: Tutorial on Architectural Acoustics

Ralph T. Muehleisen, Chair

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1eID Tutorial on architectural acoustics. Neil Shaw (Menlo Scientific Acoustics, Inc., Topanga, CA 90290) Rick Talaske (The Talaske Group, Inc., Oak Park, IL 60301), and Sylvio Bistafa (Dept. of Mechanical Engineering, Polytechnic School, University of Sao Paulo, Brazil)

This tutorial is intended to provide an overview of current knowledge and practice in architectural acoustics. Topics covered will include basic concepts and history, acoustics of small rooms (small rooms for speech such as classrooms and meeting rooms, music studios, small critical listening spaces such as home theatres) and the acoustics of large rooms (larger assembly halls, auditoria, and performance halls).