9:30

4aEA5. Investigation of vibration of polyvinlidine fluoride cylindrical film by use of acoustic probe. Minoru Toda (Measurement Specialties Inc., 460 E. Swedesford Rd., Ste. 3005, Wayne, PA 19087)

Ultrasonic pen and white board digitizing systems are a rapidly growing market for PVDF transducers, utilizing an ultrasonic transmitter in the pen tip and two stationary ultrasonic receivers. The transmitter is constructed of piezoelectric PVDF welded into a cylindrical shape. Radius vibration (breathing mode) creates an 80-kHz airborne acoustic wave. The initial cycle is used to determine the time of flight, used to calculate the pen position by triangulation. An ideal cylindrical transmitter would have a uniform 360 horizontal radiation pattern. However, practical devices have a 65% to 85% minimum/maximum ratio for the initial pressure peak. A novel acoustic probe was devised to investigate this nonuniformity. The probe tip is a needle with 0.5-mm through hole, and the acoustic wave propagates through the needle to a conventional reference microphone. The probe was positioned using a precision XYZ stage. Investigations with this probe revealed the details of the nonuniformity in horizontal radiated pressure. It was found that (1) vibration at the welded seam of the PVDF cylinder is a maximum, opposite the expected behavior, and (2) the pressure distribution profiled along the height of the cylinder has a central plateau and decreases linearly at the cylinder ends.

9:45–10:00 Break

10:00

4aEA6. Lamb waves in bulk acoustic wave resonators: Analysis of spurious resonances and design of resonators in the UHF-VHF frequency range. Alexandre Volatier, Gregory Carruyer (ST Microelectronics, 38926 Crolles, France, volatieral@chartreuse.cea.fr), Emmanuel Defay (LETI-CEA, Grenoble, France), and Bertrand Dubus (UMR CNRS 8520, Lille, France)

Bulk acoustic wave (BAW) resonators exhibit attractive properties in terms of power handling capacity and on-chip integration to realize filters in the GHz range [K. M. Lakin, IEEE Ultrason. Symp. pp. 895–905 (1999)]. In a BAW resonator, a thin piezoelectric layer (a few mm) deposited between two electrodes is driven in its thickness extensional mode of vibration. To get a high quality factor, this structure is decoupled from the substrate by a multilayer Bragg reflector or a back-etched membrane. A current problem in the design of BAW resonators is the existence of spurious resonances close to the thickness extensional mode which generate ripple in the filter passband. In this paper, these spurious modes are analyzed in terms of Lamb waves resonances. Physical modeling of BAW resonators using finite element ATILA code is presented. The influence of lateral dimensions and electrode geometry on spurious resonances is emphasized. With specific electrode design and electrical excitation, it is demonstrated that lateral modes of Lamb waves can be used to realize resonators in the 50–250-MHz range. Experiments on an AlN piezoelectric layer between Pt electrodes on a SiN membrane are presented. [Work supported by a ST Microelectronics grant (CIFRE).]

10:15

4aEA7. Ultrasonic nondestructive inspection of interface defects in anisotropic fiber-metal-laminates. Stefan A. L. Stijlen (Dept. of Imaging Sci. and Technol., Delft Univ. of Technol., Lorentzweg 1, 2628 CJ Delft, The Netherlands, s.a.l.stijlen@tnw.tudelft.nl) and Maarten C. M. Bakker (Delft Univ. of Technol., 2629 HS Delft, The Netherlands)

Ultrasonic inspection is an essential tool for the quality control of the fiber-metal-laminate Glare, which is currently applied in the production of the huge A380 Airbus aeroplane. Nowadays, the ultrasonic inspection of Glare is performed by a transmission C-scan, traditionally, or by a more advanced pulse-echo scan. In this research, a new method of data acquisition and processing is investigated. The data acquisition consists of reflection measurements for variable source-receiver offsets. The first objective is to image delaminations at or nearby interfaces. These defects can, for instance, be associated with kissing bonds due to locally imperfect coupled interfaces. The algorithm which processes and converts the data into an image is based upon the inverse scattering theory. From the acquisition level in water to the interface levels in Glare, the elastodynamic Green functions are computed including strong anisotropy, multiple reflections and conversions, refractions, and surface waves. Subsequently, interface defects are modeled as additional contrasts in compliance. Finally, an image is obtained through their optimization by minimizing a cost-functional which is the mismatch between the measured data and the synthetic data generated with the Green functions. [Work supported by STW, the Dutch technology foundation.]

10:30

4aEA8. Experimental equalization of a one-dimensional sound field using energy density and a parametric equalizer. Micah Shepherd, Xi Chen, Timothy Leishman, and Scott Sommerfeldt (Acoust. Res. Group, Dept. of Phys. and Astron., Brigham Young Univ., Provo, UT 84602, mrs74@email.byu.edu)

A simple experimental method has been developed to equalize a one-dimensional sound field using acoustic energy density. Energy density is estimated using two methods: the two-microphone transfer-function method and the two-microphone finite-difference method. An equalization filter is manually configured for each using a digital parametric equalizer. The results of the two estimation approaches are compared. Equalization filters are similarly implemented for sound pressure measured at discrete points in the field and for spatially averaged sound pressure. Results of the approaches are compared and benefits of the energy density method are discussed.

10:45

4aEA9. Sound-quality analysis of sewing machines. James J. Chatterley, Andrew J. Boone, Jonathan D. Blotter (Mech. Eng. Dept., School of Eng. and Technol., Brigham Young Univ., 435 CTB, Provo, UT 84602), Scott D. Sommerfeldt, and Thomas L. Lago (Brigham Young Univ., Provo, UT 84602)

Sound quality has become an important factor in consumer product development. Sound quality analysis procedure and results for six sewing machines ranging from entry level to professional grade machines will be presented. The focus of the study was to determine what consumers feel constitutes a pleasant sounding sewing machine and what structural modifications can be made to produce those sounds. The procedure consisted of forming small (15 person) then large (50 person) jury-based tests. These tests consisted of listening to various sound bytes and ranking the sounds as well as indicating why sounds are appealing or unappealing. The sound bytes were from actual sewing machines as well as computer generated sounds and modified machine sounds, which were constructed such that the spectral features most important in achieving a desirable product from an acoustic perspective could be statistically determined. The procedures and analysis of the jury testing results will be presented and discussed. This paper presents sound localization scans, indicating machine sound hot spots and possible sources for undesired sounds. In conclusion proposed modifications to machine structure to alter machine sound signature into a more sensory pleasant sound will also be presented.

11:00

4aEA10. Production of a noise level database of power tools used in the construction industry. Charles S. HaydenII, Edward Zechmann, and Rohit Verma (Natl. Inst. For Occupational Safety and Health, 4676 Columbia Pky., C27, Cincinnati, OH 45226, chayden@cdc.gov)

This study focused its efforts on sound power levels and noise reduction of power tools used by workers at both commercial and residential construction sites. The objective was to develop a noise control technology database consisting of power hand tools used in the construction industry with respective sound power levels and workers' sound exposure level (SEL). The database and specific noise control applications information are made available to the public on a searchable web-site. Data includes a particular tool's wavfile and time series signatures to be used for future

qualitative and quantitative analysis by other acousticians accessing the database. With this information, reasonable assumptions can be made as to the potential occupational noise exposure expected for various occupations, tasks, etc. and as to potential sources of noise within the powered hand tool itself. The database captures tool types, tool models, tool manufacturers, and decibel power level. The database is expandable to include new tools and new manufacturers as the power tool population changes over time. These efforts support the reduction of noise induced hearing loss among construction workers by providing ''buy quiet'' and ''designed quiet'' information to power tool buyers and end users.

THURSDAY MORNING, 18 NOVEMBER 2004 PACIFIC SALON 3, 8:30 TO 11:45 A.M.

Session 4aMU

Musical Acoustics: Physics of Musical Instruments

George A. Bissinger, Cochair
Department of Physics, East Carolina University, Greenville, North Carolina 27858

Daniel O. Ludwigsen, Cochair
Science and Mathematics Departments, Kettering University, 1700 West Third Avenue, Flint, Michigan 48504-4898

Contributed Papers

8:30

4aMU1. Galilei experiments and common sense. R. Dean Ayers (Dept. of Phys. and Eng. [Adjunct], Southern Oregon Univ., 1250 Siskiyou Blvd., Ashland, OR 97520)

Galileo Galilei showed us by example how to put hypotheses about the natural world to the test of scientific experiments. It is very likely that his attitude of healthy skepticism toward his own ideas and those of others was instilled in him by some work in musical acoustics. His father, Vincenzo (or Vincentio), was a prominent music theorist and composer as well as an accomplished lutenist. During his adolescence Galileo assisted Vincenzo in practical studies on the behavior of vibrating strings. That research examined the influence of various parameters on the pitch of a string (and hence its frequency), disproving some incorrect guesses. We are now in an age when many of our students are unduly influenced by popularized reports on exotic and seemingly bizarre open questions in relativity, cosmology, and elementary particles. That exposure encourages them to abandon their common sense and skepticism when they take a science course. Our specialty can provide a valuable counterexample by letting students perform exploratory, quantitative studies on the strings of the original Galilei experiments or on other vibratory systems. We can all benefit by remembering the lessons learned from such work. [Work supported in part by the Paul S. Veneklasen Research Foundation.]

8:45

4aMU2. End correction for an open pipe from measured resonance frequencies. Daniel O. Ludwigsen and Brandon J. Dilworth (Dept. of Sci. and Math., Kettering Univ., 1700 W. Third Ave., Flint, MI 48504)

As briefly noted in freshman physics textbooks, resonance in open-ended pipes depends on an effective length that is greater than the actual length of the tube. The additional end correction varies with the termination at the open end. By measuring several peak frequencies in a response function (pressure in the pipe over source excitation), we have calculated the end correction for open ends of PVC tubes of varying diameters with several flanges of increasing size. Temperature effects were carefully controlled, and resonance frequencies recorded to within 0.01 Hz. Averaged results are in agreement with literature and theoretical expectations, but anomalies and unexpected results will also be presented.

9:00

4aMU3. Period doubling in free reeds coupled to pipe resonators. Evan M. Goetzman (Univ. of Minnesota, Minneapolis, MN 55455) and James P. Cottingham (Coe College, Cedar Rapids, IA 52402)

An earlier study investigated behavior of the reed–pipe combination consisting of an American organ reed installed at the closed end of a cylindrical pipe. Over a wide range of pipe lengths and playing pressures, the sounding frequency is slightly below a pipe resonance frequency and can be pulled considerably below the natural frequency of the reed. [Vines *et al.*, J. Acoust. Soc. Am. **114**, 2349 (2003)]. Additional measurements of reed vibration for these reed–pipe combinations for low frequency (48 Hz) free reeds show that as the playing pressure is increased there is typically a sudden transition to period doubling or, in some cases, tripling or quadrupling. Some pressure intervals exist in which apparently chaotic reed vibration occurs, or in which the reed will not vibrate at all. Period doubling was found to occur over varied values of pipe length, pipe diameter, and the use of two different reeds with matching resonance frequencies. General trends in the onset and steady-states of period doubling are described using measured spectra and spectrograms of both reed motion and radiated sound pressure over a continuous range of playing pressure. [Work supported by NSF REU Grant No. 0354058.]

9:15

4aMU4. The motion of harp strings. Chris Waltham (Dept. of Phys. and Astron., Univ. of Britich Columbia, Vancouver, BC V6T 1Z1, Canada, waltham@physics.ubc.ca)

A harp is an instrument with a set of plucked strings that excite the sound board directly, without the medium of a bridge. The strings are positioned at an acute angle to the plane of the sound board. The quality of the sound produced depends on the motion of the string and its interaction with the resonances of the sound board. The string motions of several small and large harps have been studied using small, fast position sensors. The results are compared to those of a simple nonlinear model based on the measured elastic properties of the string materials, and those of the sound board. The implications for the sound production are discussed.