Nonlinear Acoustics: Analogs of Phenomena in Nonlinear Optics

Friday, January 31, 1992 4:00 p.m.

Dr. Mark F. Hamilton
Department of Mechanical Engineering
The University of Texas at Austin

Although the study of nonlinear acoustics predates nonlinear optics by more than a century, nonlinear optics has been exploited much more for technological applications than has nonlinear acoustics. The main difference is dispersion (dependence of phase speed on frequency): it is strong in optics and weak in acoustics. Strong dispersion permits efficient parametric amplification and the existence of solitons, whereas weak dispersion leads to shock waves and therefore large energy losses. Phenomena that are unique to nonlinear acoustics (shock formation, parametric antennas) and which have analogs in nonlinear optics (second harmonic generation, waveguide interactions, self-focusing, phase conjugation, Raman scattering, superradiance) are reviewed in this seminar.

Acoustic Modes of a Wine Glass

Friday, February 7, 1992 4:00 p.m.

Nathan Kane
Department of Mechanical Engineering
The University of Texas at Austin

In this seminar, the ringing that results from rubbing a wine glass rim with a wet finger is investigated. Normally, only one tone, corresponding to the fundamental of the glass, can be produced by rubbing a glass by hand. In a demonstration, in which the glass is spun on a turntable, several higher modes of vibration are produced using two soft erasers to excite the glass. The demonstration shows that the mode of vibration producing the noise is flexural vibration of the glass wall (the same mode of vibration that occurs in bells), and that the erasers that excite the glass always act at the nodes of the vibration produced. Along with the demonstration, an explanation is proposed as to how stick slip of the erasers could produce the vibration that is observed.

N Wave Propagation through Turbulence as Scale Model of Sonic Boom Propagation through the Atmosphere

Friday, February 21, 1992 4:00 p.m.

Bart Lipkens
Applied Research Laboratories
and
Department of Mechanical Engineering
The University of Texas at Austin

Typical measured sonic boom rise times are two to five times longer than rise times calculated using molecular relaxation theory [J. Kang, Ph.D. thesis, Pennsylvania State University (May 1991); A. D. Pierce and V. W. Sparrow, NASA First Annual High-Speed Research Workshop, Williamsburg, Virginia, May 1991]. Pierce et al. have proposed that the difference is due to atmospheric turbulence. A model experiment has been set up to study the influence of turbulence on waveform and rise time of spark produced N waves. The N waves propagate through turbulence generated by a plane jet. The model turbulence is scaled down from atmospheric turbulence by approximately the same factor as the model N wave is scaled down from the sonic boom. Our experiments show that passage through the turbulence produces a wide variety of changes in the N waveform. Spiked and rounded N waves are observed, and average rise time is increased by a factor of about 2. A tentative observation based on data obtained so far is that turbulence never decreases rise time. [Work supported by NASA.]

Focused Shock Waves Produced By Spark-Source Lithotripters

Friday, February 28, 1992 4:00 p.m.

Dr. Mark Hamilton
Department of Mechanical Engineering
The University of Texas at Austin

Lithotripters use focused shock waves to disintegrate kidney stones and gallstones. One way to generate the shock wave is with a spark source at the near focus of an ellipsoidal mirror. The acoustic energy in the outgoing spherical wave produced by the spark is reflected from the mirror and concentrated at the far focus of the ellipse, where the stone is located. In this presentation, a transient, small-signal solution is developed for the reflected pressure field along the axis of the mirror. Waveforms predicted by the solution are compared with lithotripsy pulses reported in the literature and with experiments performed recently at UT by Wright and Blackstock.

Interaction of Multiple Spark-Generated Bubbles in a Compressible Liquid

Friday, March 6, 1992 4:00 p.m.

Jeffrey A. Cook
Applied Research Laboratories
and
Department of Physics
The University of Texas at Austin

Spark discharges have been used for many years as a source of sound and high pressures. Previous research on spark-generated bubbles has been concerned primarily with the dynamics of a single bubble. Multiple bubble studies have often used an external sound field to excite oscillation in clouds of bubbles. The research summarized here considers the dynamics of a collection of bubbles, initiated by similar discharges at separations sufficiently small as to allow them to interact during their primary oscillation.

The physical processes which take place in the generation of sound from an underwater electrical discharge are interdisciplinary, encompassing the fields of acoustics, fluid dynamics, and thermodynamics, among others. The interaction of these inseparable processes in an observable event provides an opportunity to unify microscopic and macroscopic models within a single comprehensive model. The resulting model is then used to characterize the bubble and interaction dynamics over a wide range of experiment parameters. An attempt is made to extrapolate results to discharge energies and experimental configurations which are not easily attainable at this level of research. In addition to examining various changes in the dynamics with depth, energy, etc., effects from changes in other experimental parameters (such as the power input profile, for example) are easily examined with the same model.

The Energy Partition of the Underwater Spark Sound Source

Friday, March 13, 1992 4:00 p.m.

Randy M. Roberts
Department of Physics
The University of Texas at Austin

The underwater spark is being investigated as a practical source of intense, low frequency sound. The spark generates an oscillating bubble which produces intense sound with a fundamental frequency corresponding to the bubble's period. The acoustic energy and its fundamental frequency depend strongly on the amount of energy imparted to the bubble. From experimental investigations it has been shown that the spark generated bubbles are not totally efficient sources of underwater sound. Our group has identified several energy loss mechanisms in the bubble. In this presentation I will discuss blackbody radiation, bubble wall ablation, and molecular dissociation as candidate mechanisms. I will present the results of computational models and compare them to the experimental data.

Second Harmonic Generation in a Focused Sound Beam that is Reflected and Transmitted at a Curved Interface

Friday, April 3, 1992 4:00 p.m.

Inder Makin
Biomedical Engineering
The University of Texas at Austin

The talk will present a model for second harmonic generation in a focused Gaussian beam that is reflected and transmitted at a slightly curved interface. Second harmonic generation is a nonlinear effect that accompanies waveform distortion at sufficiently high acoustic intensities. Arbitrary absorption and complex surface impedance are taken into account. The nonlinear parabolic (KZK) wave equation is used to derive a closed form solutions for the second harmonic pressure and power. When absorption is negligible, solutions for the transmitted second harmonic field can be derived from the reflected field solutions with a simple transformation. Graphical results for different source-target parameters will be presented. Practical implications of the analysis will be described, e.g., biomedical ultrasound and acoustic microscopy.

Practical Studies of the Impact of Environmental Noise

Friday, April 10, 1992 4:00 p.m.

Jack B. Evans, P.E.
Jack Evans & Associates, Inc.
Engineered Vibration Acoustic & Noise Solutions

Building design criteria and construction parameters, with a focus on environmental noise from mechanical equipment, including engineer generators, fire pumps and cooling towers will be presented. Case histories will be discussed, including on-site observations and findings at U.S. Embassies in Georgetown, Guyana (S.A.) and San Salvador, El Salvador (S.A.)

A Variational Model for Bubbly Sediments with a Distribution of Bubble Radii

Friday, April 24, 1992 3:00 p.m.

James A. Hawkins, Jr.
Mechanical Engineering
The University of Texas at Austin

We have developed, using Hamilton's variational principle, a model which describes the propagation of acoustical disturbances (sound) in bubbly sediments. The sediment is taken to be a solid frame saturated by a fluid (in the sense of a Biot-Stoll material), in which the fluid contains bubbles. The major contribution of our work is to allow the bubble population in the fluid to have a known distribution of bubble sizes. The work in this dissertation is made up of three parts: first we develop an acoustical model for a bubbly fluid, then we proceed to the bubbly sediment model, and finally, we solve the normal reflection problem for both a bubbly fluid and a bubbly sediment. In particular, we present the dispersion relation for each case: the bubbly fluid and bubbly sediment; and from the dispersion relations, we compute the phase velocity and attenuation. In the reflection problem, we present the reflection coefficient for a bubbly half-space, first for the bubbly fluid and then for the bubbly sediment. The effects of a distribution of bubble sizes are illustrated by comparing the results using different bubble size distributions in both the bubbly fluid and the bubbly sediment.

Presentations for the 123rd ASA Meeting Salt Lake City, Utah

Friday, May 1, 1992 3:00 p.m.

Michalakis A. Averkiou
"Propagation of pulsed finite amplitude sound beams in a liquid with strong absorption"

Michalakis A. Averkiou
"Reflection of focused sound beams from curved surfaces"

Bart Lipkens
"The propagation of plane N waves through a statistically isotropic turbulent field as a singular perturbation problem"

Douglas E. Reckamp
"Propagation of finite amplitude sound in a waveguide with a parabolic sound velocity profile"

Thomas W. VanDoren
"Water fountains produced by intense standing waves in air"

Evgenia A. Zabolotskaya and Yu A. Ill'insky
"Cooperative radiation of acoustic waves by gas bubbles in a liquid"

Finite-Amplitude Sound Propagation in Multiple Waveguide Modes

Friday, September 11, 1992 4:00 p.m.

Tom Van Doren
Department of Mechanical Engineering
The University of Texas at Austin

This wildly exciting seminar will describe a theoretical and experimental investigation of the propagation of finite-amplitude sound in multiple waveguide modes of a rectangular duct with rigid walls.

Two quasilinear analytical solutions for second harmonic generation will be described. The first analytical solution is based on a hyperbolic (Westervelt) wave equation, and the second is based on a parabolic (KZK) wave equation. The analytical solution of the parabolic wave equation will provide a benchmark for comparison with a numerical solution of the parabolic wave equation (the numerical solution is currently under investigation).

The theoretical predictions will be compared to results from experiments performed in an air-filled rectangular waveguide excited by rectangular sources driven at frequencies ranging from 1 kHz to 50 kHz. The sources are sized and located such that only certain waveguide modes should be excited. Experiments where sound is generated in 1 to 7 modes will be described. All sources are capable of generating sound pressure levels in excess of 130 dB (re 20 μPa), so finite amplitude propagation (and thus generation of detectable higher harmonics) is assured.

Nonlinear Rayleigh Wave Propagation in an Isotropic Solid

Friday, September 18, 1992 4:00 p.m.

E. A. Zabolotskaya
Department of Mechanical Engineering
and
The General Physics Institute
Russian Academy of Sciences

Nonlinear Rayleigh wave propagation is investigated theoretically. The analysis is based on the Hamiltonian formalism. Nonlinear propagation and distortion of plane waves is considered with this method (technique). Coupled equations for the harmonic components are derived. The equations for harmonic amplitudes have been integrated numerically. Results of numerical solutions are presented. The evolution equation for nonlinear surface acoustic waves (SAW) is derived. The possible existence of stationary Rayleigh waves is discussed.

Propagation of Longitudinal and Shear Waves Through Ice

Friday, September 25, 1992 3:30 p.m.

Elizabeth Langworthy Miller
Applied Research Laboratories

The possibility of using a geophone to detect ocean acoustic waves beneath a layer of ice is investigated. A very brief review of continuum mechanics is given, along with the velocity potentials of the waves in the ice, air, and water. Absorption is derived from transmission loss. Surface waves, including Rayleigh waves, are discussed and critical angles are derived. Boundary conditions are used to solve for the amplitude of vertical particle velocity. Plots of vertical particle velocity vs. frequency and angle are divided into regions separated by critical angles. A brief discussion of continuing work is given.

Spectrum Levels of Bubble-Related Ambient Sea Noise

Friday, October 9, 1992 3:30 p.m.

Stirling Scott Dodd
Applied Research Laboratories

A dip at two kilohertz in the ambient sea noise sound level spectrum, taken with the Captor Improvement Project Vertical Line Array, is described. Limitations of existing ambient sea noise models are discussed. An approach is detailed for the creation of a model of the sound spectrum shaping of ambient bubble noise in the 1 to 10 kHz frequency range. The surface source spectral density of a single bubble and bubble cloud resonance is examined. These two mechanisms are shown to create noise in the 1 to 10 kHz frequency range. The density of oceanic bubble populations is described. A brief discussion of continuing work is given.

Propagation of Pulses in Liquids with Strong Absorption

Friday, October 23, 1992 4:00 p.m.

Michalakis A. Averkiou
Mechanical Engineering Department
The University of Texas at Austin

Measurements of intense pulses generated by directive sources in liquids with strong absorption are compared with theoretical predictions based on a time domain numerical solution of the KZK nonlinear parabolic wave equation. The classic phenomenon referred to as self-demodulation of sound, predicted by Berktay, is examined. A quasilinear model for propagation of pulses in absorptive liquids along the axis of the source is also presented. Experiments performed at megahertz frequencies in glycerin were compared with both the time domain numerical solution of the KZK equation (on-axis and off-axis) and the quasilinear model (on-axis). At the frequencies used the absorption was 10 dB/mm. Amplitude as well as frequency modulated tone bursts were considered. Good agreement between the theoretical models and the experimental results was obtained. In addition, the experiments revealed phenomena caused by the effect of strong absorption, not nonlinearity, on the transient portions of the primary wave.

Presentations for the 124th ASA Meeting New Orleans, Louisiana

Monday October 26, 1992 3:00 p.m.

Leick Robinson
“A ray theory model of sonic boom propagation through a turbulent ground layer”

Bart Lipkens
“Further reports on the propagation of spark produced N waves through turbulence”

Robin O. Cleveland
“Waveform freezing of sonic booms in the atmosphere”

Michael R. Bailey
“Isolation of a negative pressure pulse by means of diffraction”

Davis J. Shull
“Harmonic interactions in plane and cylindrical nonlinear Rayleigh waves”

Evgenia A. Zabolotskaya
“On the existence of stationary nonlinear Rayleigh waves”

Ilene J. Busch-Vishniac
“The case of magnetically driven microactuators”

David T. Blackstock
“Stories of F. V. Hunt’s Acoustics Research Laboratory (Harvard) and about nonlinear acoustics” [Invited Paper]

Periodic and Pulsed Sawtooth Wave Propagation through Nonlinear and Inhomogeneous Media

Wednesday, October 28, 1992 4:00 p.m.

Professor Oleg V. Rudenko
Department of Physics
Moscow University, Russia

A theoretical model for nonlinear geometrical acoustics is developed by simplifying the general and parabolic nonlinear wave equations on the basis of high frequency approximations. Physical phenomena associated with high acoustic intensities, such as nonlinear refraction and self-defocusing, and maximum amplitudes of focused periodic and pulsed sawtooth waves, are defined by limiting parameters. Sawtooth wave propagation through an inhomogeneous atmosphere and through a stratified ocean is discussed. Some experimental results are presented.

Acoustic Impulse Response Measurements Using Maximum Length Sequences

Friday, November 6, 1992 4:00 p.m.

David Nelson
Acoustic Systems
Austin, Texas

The impulse response of a space may be obtained by cross-correlation of a “white noise” signal broadcast into the space and that arriving at a given point. An especially favorable choice for the stimulus is a Maximum Length Sequence because of its low crest factor, deterministic structure and computational efficiencies afforded by the Fast Hadamard Transform which accelerates the cross-correlation calculation. The impulse response of a variety of spaces, real and virtual, will be presented in audio and graphical formats. Finally, examples of auralized speech and music, obtained by convolving the impulse response with dry recordings, will be played. Other topics which may be touched upon if time permits: limits of time and frequency resolution, Energy-Time Curves, Speech Intelligibility Index, Reverberation Time, Schroeder backwards integration, small room measurements, deconvolution of source signature, binaural measurements.

Surface Acoustic Waves Excited by Laser Pulses in Isotropic Solids and in Single-Crystals

Monday, November 9, 1992 4:00 p.m.

Al. A. Kolomenskii
General Physics Institute
Moscow, Russia

Theoretical and experimental results are presented on the laser generation of surface acoustic waves in isotropic solids and in single-crystals. Two main mechanisms are considered: a thermo-optical one and a mechanism connected with the ablation of a substance. In anisotropic crystals the concentration of acoustic energy flux in certain directions occurs which is known as the phono focusing effect. The first observations of this effect in several single-crystals with surface acoustic waves were performed. The directions of high amplitude of the acoustic wave were visualized by shaking off micron-size particles deposited beforehand on the surface. Quantitative measurements were performed by means of a laser beam deflection probe technique. An analytic model for the focusing of surface acoustic waves was also developed.

History and Development of the Modern Acoustic Horn

Friday, November 20, 1992 4:00 p.m.

John T. Post
Electrical and Computer Engineering Department
The University of Texas at Austin

Modern day acoustic horns have an extensive and colorful past. The understanding and use of the acoustic horn is traced from its origins as a device for ‘summoning,’ to its use as an impedance matching device necessary for maximum power transfer, to the current trend of ‘constant directivity’ horns used in high quality sound reproduction. Factors in the design technique for horns are also addressed.

Real Time Computer Simulation of Concert Hall Acoustics

Friday, December 4, 1992 2:00 p.m.

Turker Kuyel
Department of Music
The University of Texas at Austin

Real time computer simulation of room acoustics has important applications in music production, recording and also in multimedia. Computer generated acoustic environments also have important applications in making architectural decisions on the construction of concert halls, etc. Real time room simulation algorithms have been developed for the digital signal processor DSP56001. Our simulations have reached the perceptual quality to serve the demanding musician. Aspects of digital simulation of room acoustics and the simplification of the simulation algorithms for DSP56001 implementation will be discussed. The real time room simulator which has been developed at University of Texas will be demonstrated.