Nonlinear Waves in Rocks

Friday, January 29, 1993 4:00 p.m.

G. Douglas Meegan
Earth and Environmental Sciences Division
Los Alamos National Laboratory

Rocks are typically highly disordered solids which consist of complicated networks of microfractures and pore spaces. Consequently, rocks exhibit a strong acoustic nonlinearity when compared to intact materials. The results of wave propagation, resonance, and quasi-static measurements of nonlinear effects in rocks will be presented. The experiments show that the nonlinear parameters for rocks are two orders of magnitude greater than those of gases, liquids and most other crystalline or polycrystalline solids. The implications and possible applications of nonlinear wave propagation in the earth will be discussed.

Nonlinear Acoustics: Fundamentals and Some Applications

Friday, February 5, 1993 4:00 p.m.

Professor David T. Blackstock
Applied Research Laboratories and
Mechanical Engineering Department
The University of Texas at Austin

Nonlinear acoustics (also called finite-amplitude acoustics) is about very loud sound, that is, waves of very high intensity. The main difference between ordinary (small-signal) acoustics and nonlinear acoustics is in propagation speed. All points on a small-signal wave travel with the same speed. For a finite-amplitude wave, however, propagation speed depends on the local particle velocity and therefore varies over the waveform. The peaks of the wave travel fastest, the troughs slowest. Consequently, the finite-amplitude wave distorts as it propagates. Many novel phenomena result. Simple applications for periodic sound include the conversion of a monochromatic wave into a sawtooth, shock formation, increased absorption, saturation, and modulation and suppression of one sound by another. In more complicated wave fields, such as sound beams, the interaction between nonlinear effects, absorption, and diffraction produces a variety of unusual effects. Two other kinds of intense sound – noise (such as aircraft noise) and pulses (such as the sonic boom, explosion waves, and lithotripsy radiation) – have their own interesting applications.

A Combined Ultrasound and Fluorescence Spectroscopy System for In Vivo Tissue Characterization

Friday, February 19, 1993 4:00 p.m.

Youseph Yazdi
Department of Electrical and Computer Engineering
The University of Texas at Austin

Intravascular ultrasonic imaging permits physicians to view real time cross sectional images of blood vessels in the body. This permits the direct measurement of vessel stenosis (narrowing) due to plaque formation and other structural anomalies found in coronary artery disease (CAD) , the leading cause of death in the US. Fluorescence spectroscopy is also useful the diagnosis of CAD in vitro, providing information on the chemical composition of the tissue. A method is described which combines IV ultrasound and laser-induced fluorescence spectroscopy for the diagnosis of CAD in vivo. This talk will give a description of each technique, as well as a discussion of the problems unique to the combination of the two methods.

An Investigation of Elastic and Dielectric Loss Processes in Piezoelectric Polymers and Their Effect on Broadband Sonar Transducers*

Tuesday, February 23, 1993 3:30 p.m.

Deborah A. Summa
Applied Research Laboratories

The discovery of strong piezoelectric activity in macromolecules such as poly(vinylidene fluoride) (PVDF) and its copolymers has made possible a class of flexible, lightweight, inherently broadband transducers which exhibit virtually no lateral coupling. Recent technological advances have made possible the mass production of uniform thick tiles with sufficient sensitivity to be considered for sonar applications. Such materials have enormous potential, particularly in the area of extended sensors and acoustically transparent hydrophones.

Classic electromechanical transducer models (e.g., Mason's model) typically suppose an ideal lossless substrate. While this assumption has proven adequate for quartz and ferroelectric ceramics, it is inappropriate for polymeric materials. We extend existing models to general piezoelectrics by (1) incorporating dielectric and mechanical losses in general, and (2) considering the frequency, temperature, and pressure dependence of both the storage and loss components of the elastic and dielectric moduli of PVDF and P(VDF-TrFE) copolymers. Phenomenological models and molecular estimation techniques are used to augment sparse data typically supplied by the manufacturer. The improved material description is used to assess the acoustic performance of a typical thickness-mode PVDF hydrophone over a range of environmental parameters of interest in sonar.

*Final oral defence of Ph.D. dissertation; Mechanical Engineering Department.

A Model for High Frequency Acoustic Backscatter from Gassy Sediments at Shallow Grazing Angles

Friday, March 5, 1993 4:00 p.m.

Frank A. Boyle
Applied Research Laboratories

Recent experimental backscatter data suggests a volume scattering mechanism involving trapped gas bubbles. A model for shallow grazing angle high frequency acoustic backscatter from sediment is developed. The model begins with a pore distribution function, obtained from measurements of the grain size distribution and observations of the pore size distribution between randomly packed hard spheres. By making the assumption that an interstitial bubble's size is governed by the size of its surrounding pore, a bubble size distribution is obtained. The bubble distribution is then combined with an existing model for backscatter from single bubbles to arrive at a backscatter model for gassy sediments. Comparisons are made between model predictions and existing experimental measurements.

Static vs. Dynamic Properties of Rocks

Friday, March 12, 1993 4:00 p.m.

Professor Mukul M. Sharma
Department of Petroleum Engineering

A comparison of Young's moduli and Poisson's ratios obtained from ultrasonic laboratory measurements with static moduli obtained under identical stress conditions shows that the Young's moduli are 1 to 6 times higher under ultrasonic loading conditions. A comparison of these two laboratory measured quantities with sonic log derived moduli measured at 20 kHz indicates that $E_{ultrasonic} > E_{sonic} > E_{static}$. The clay content and porosity of the samples varied from 1% to 54.5%, respectively. This clearly suggests that a wide variety of sandstones behave in a viscoelastic manner. The magnitude of the variation with frequency is a function of the clay content, grain size, shape of intergranular contacts, mineralogy and fluid saturations. A model is presented that describes this observed viscoelastic behavior.

High Amplitude Photoacoustic Pulses and Their Application

Friday, March 26, 1993 4:00 p.m.

Professor Vladislav G. Mikhalevich
General Physics Institute Russian
Academy of Sciences, Moscow

This seminar reviews research activity in laser photoacoustics at the General Physics Institute in Moscow. Laser light can be used to excite strong acoustic fields in which nonlinear phenomena become significant. An advantage of this method is precise control of the spatial and temporal properties of the sound fields. Current photoacoustics problems include extension to higher frequency bands and improving the efficiency of photoacoustic energy conversion. The development of 3-micron range erbium lasers

operating in a mode-locking regime provided a new way to solve these problems, since several liquids have very high absorption coefficients at these wavelengths. By appropriate selection of the light absorption region it is possible to focus the sound in a predetermined region of a medium and provide a substantial increase in the initial wave amplitude. In this context the influence of hydrodynamical nonlinearity and diffraction on the process of strong pulse generation and focusing will be considered under different conditions. New applications of powerful photoacoustic sources, e.g., for cleaning semiconductor wafer surfaces with laser generated SAWs, and "surface phonon focusing" in anisotropic material, will be discussed.

Some Effects of Acoustic Radiation Pressure: Bubble and Drop Dynamics and Four-Wave Mixing Mediated by a Suspension

Friday, April 2, 1993 4:00 p.m.

Professor Philip L. Marston
Department of Physics
Washington State University
and
Visiting Research Fellow
Applied Research Laboratories

The average or "radiation" pressure of ultrasound can produce large responses in fluid systems when there is sufficient time for the generally weak second-order forces to act. Examples to be considered include low frequency shape oscillations and other responses of bubbles and drops. Observations making use of radiation pressure of the dynamics of bubbles were performed on the USML-1 Shuttle flight of 1992 in NASA's new Glovebox facility and these will be summarized. Another example to be described is a novel interaction of sound with sound mediated by a suspension. In that experiment, particle migration gives rise to coherent acoustic Bragg scattering.

Applications of Pulse-Echo Ultrasonic Measurements in Oil and Gas Well Drilling Operations

Friday, April 16, 1993 4:00 p.m.

James A. Davidson
Department of Petroleum Engineering
The University of Texas at Austin

During the past twenty years, a number of applications for ultrasonic measurement techniques have been developed for the oil industry. This seminar will review many of those developed to provide information useful in gas well drilling operations. A brief overview of the basic principles involved in oil well drilling will be presented for those not familiar with drilling operations along with a discussion of the basic acoustic, electromagnetic, and nuclear formation evaluation measurements which are made in a typical exploration or development well. Pulse-echo ultrasonic measurement techniques have been developed to improve the efficiency and safety of the drilling operations and to improve the quality of the formation evaluation measurements. These include measurements to determine the borehole size and shape; measurements

to detect the influx of gas into the wellbore; measurements to assess the stability of the borehole wall; and measurements to provide images of the borehole wall. Recently, a research project was initiated in the Department of Petroleum Engineering to determine whether information about the petrophysical properties of reservoir rocks can be obtained from the analysis of the reflected waveforms recorded in these measurements. The results of the experiments conducted thus far will be reviewed and plans for future work will be discussed.

Graduate Research in Ocean Engineering, with Examples from the JOINT MIT-WHOI Program on Numerical Modeling of Acoustic Reverberation from the Ocean Bottom

Monday, April 19, 1993 1:00 p.m.

Professor Henrik Schmidt
Department of Ocean Engineering
Massachusetts Institute of Technology

No abstract available.

Linear and Nonlinear Acoustic Bloch Wave Propagation in Periodic Waveguides*

Friday, April 23, 1993 3:30 p.m.

Charles E. Bradley
Mechanical Engineering Department
The University of Austin at Texas
and
Applied Research Laboratories

In this seminar the results of a theoretical and experimental investigation of the acoustic Bloch waves that occur in a class of periodic waveguides is presented. Many unusual wave phenomena, some known and some new, are discussed. Among these phenomena are (1) reflection coefficient of larger than unit magnitude, (2) near-infinite group velocities, (3) narrowband pulses that shift in frequency and accelerate as they propagate, (4) narrowband pulses that Fourier transform themselves as they propagate, and (5) nonlinear waves that generate backward travelling second harmonic distortion components.

*Final oral defense of Ph.D. dissertation.

Experimental and Numerical Study of the Propagation of N Waves through Turbulence*

Friday, May 7, 1993 3:30 p.m.

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

The results of an experimental and numerical study on the propagation of N waves through turbulence is presented. The experiment simulates the propagation of sonic booms through atmospheric turbulence. The N waves are generated by a spark-source, and the turbulence is produced by a plane jet. Measurements of the waveforms of N waves show that the model experiment is successful in simulating the propagation of sonic booms through atmospheric turbulence. A new numerical model is developed, in which discrete realizations of a turbulent velocity field are generated. A linear acoustic wave equation is developed that describes propagation of plane N waves through turbulence. The results from the numerical model are confirmed by measurements.

*Final oral defense of Ph.D. dissertation.

Propagation and Absorption of Finite-Amplitude Sound in Biomedical Tissues*

Thursday, May 13, 1993 10:00 a.m.

Ping-Wah Li
Department of Physics
The University of Texas at Austin

A theoretical investigation of the propagation and absorption of finite-amplitude acoustic waves in media with thermoviscous and multiple relaxation mechanisms will be presented. A nonlinear wave equation, called the generalized Burgers equation, is derived for this purpose. Analytic and asymptotic solutions for this equation will be discussed. The results are used to calculate the finite-amplitude absorption coefficient and the temperature rise in biomedical tissues due to the absorption of the sound energy. It is found that, due to the nonlinear distortion effect, the absorption and the temperature rise in tissue can be significantly higher than that predicted by linear theory.

*Final oral defense of Ph.D. dissertation.

Faculty Introductions and Overviews of Current Research Projects

Friday, September 3, 1993 4:00 p.m.

Members of the Acoustics Faculty
Departments of Mechanical Engineering and Electrical Engineering
The University of Texas at Austin

The purpose of this seminar is to introduce members of the acoustics faculty and their research associates to anyone who is either new at UT or simply curious. Overviews of current projects will be provided by David Blackstock, Ilene Busch-Vishniac, Mark Hamilton, Elmer Hixson, and anyone else who feels inclined to describe his/her activities.

Bioeffects of Positive and Negative Acoustic Pressures

Friday, September 10, 1993 4:00 p.m.

Michael Bailey
Department of Mechanical Engineering
The University of Texas at Austin

The violence of gas bubble collapse poses a potential danger in medical ultrasound procedures, and tissues dense gas, such as lung, are among the most sensitive. Developed from predictions of expansion and inertial collapse of bubbles in water, conventional wisdom is that negative pressure collapses bubbles more effectively than positive pressure. The possibility that tissue might constrain the bubble's expansion is often overlooked. Here, positive and negative thresholds were determined for hemorrhage in mouse lung and for death in Drosophila (fruit fly) larvae. The results indicate that positive pressure is at least as effective as negative pressure.

Statistical Problems in Nonlinear Acoustics

Friday, September 17, 1993 4:00 p.m.

Dr. Vera A. Khokhlova
Acoustics Division, Physics Department
Moscow State University

An overview will be provided of research performed on statistical problems in nonlinear acoustics in the Department of Physics at Moscow State University. Attention will be focused on the propagation of random sound waves containing shocks. A model of a random phase screen will be considered, which permits theoretical investigation of the influence of nonlinear attenuation and random focusing effects on the statistical properties of the acoustic field behind an inhomogeneous layer. In particular, the distribution of the acoustic pressure amplitude and the spatial structure of the field will be examined.

Presentations for the 126th ASA Meeting Denver, Colorado

Friday, September 24, 1993 4:00 p.m.

John T. Post
Department of Electrical Engineering
The University of Texas at Austin
Rayleigh’s Horn Equation

and

Michalakis A. Averkiou
Department of Mechanical Engineering
The University of Texas at Austin
Measurements of Finite Amplitude Pulses Radiated by Plane Circular Pistons in Water

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Calculations of Mutual Scattering Between Two Spheres

Friday, October 1, 1993 4:00 p.m.

C. L. Morfey
Institute of Sound and Vibration Research
University of Southampton, UK

Results will be presented from recent work on the sound field radiated by the surface vibration of two spheres in an infinite fluid medium. The application originally envisaged was to impact noise of colliding solid spheres, as measured by Koss and Alfredson (in air) and by Thorne and Foden (in water). These studies also included theoretical predictions, but neither allowed for mutual scattering. Besides its application to impact noise, the two-sphere model is of general interest and may be regarded as a prototype scattering problem, since the spacing of the two spheres and their relative diameters may take any value. A matrix solution, formulated in terms of spherical surface harmonics, has been implemented on MATLAB. Convergence issues turn out to be important because the spherical harmonic series for each sphere has to be truncated after a small number of terms.

Acoustics and Acoustics Education in China

Monday, October 11, 1993 4:00 p.m.

Dr. Guan Dinghua
Institute of Acoustics
Academia Sinica
Beijing, China

No abstract available.

A Study of the Fracture Impedance Method

Friday, October 22, 1993 4:00 p.m.

Ahmed Shaaban
Department of Mechanical Engineering
The University of Texas at Austin

The fracture impedance method is a new technology for estimating the dimension and characteristics of downhole, hydraulically introduced fractures along the wellbore. The method is based on the assumption that the existence of the fracture changes the impedance of the wellbore. Thus, the dimension of the fracture could be assessed by analyzing the characteristics of wave motion measured at the wellhead. In this study, the fracture impedance method is reformulated on the basis of continuum mechanics. The fracture is treated as a Helmholtz resonator in the analysis of wave motion in the fluid-filled wellhole. The transfer function for the entire system is thus derived. Preliminary calculations have demonstrated that there is a resonance frequency that corresponds to the hydraulic fracture.

A Finite Element Bond Graph Model for the Piezoelectric Thickness Vibrator

Friday, October 29, 1993 4:00 p.m.

Won-Kyu Moon
Department of Mechanical Engineering
The University of Texas at Austin

A finite element equivalent model for the thickness vibrator is formulated. This formulation leads to a new definition of the generalized displacements for a continuous system. The newly defined coordinates are easily interpreted physically and easily used in analysis of the system performance. The new bond graph model for the piezoelectric thickness vibrator is compared to the Mason equivalent circuit model. The bond graph model offers the primary advantage of providing more physical insight and understanding because of the use of multiport energic elements. While the model developed here is valid for the thickness vibrator only, the modeling method presented is general in scope and can be applied to arbitrary physical systems.

Adaptive Multi-Level Substructuring in Structural Acoustics Computation

Friday, November 5, 1993 4:00 p.m.

Matthew Kaplan
Department of Aerospace Engineering and Engineering Mechanics
The University of Texas at Austin

Computational structural acoustic analysis of submarines can be prohibitively expensive in certain frequency ranges because of the geometric complexity of the structure. A method for dealing with high order finite element models of submarines will be presented, which uses a subdivision of the submarine into substructures, each of which is divided into its own substructures, etc. Within each substructure, the finite element model is transformed to a representation in terms of approximate modes of vibration, which can be truncated severely to obtain a greatly reduced model. An adaptive procedure is used to determine which modes should be included in the model for optimal accuracy.

Propagation of Sound in a Lined Circular Duct with Sheared Mean Flow

Friday, November 12, 1993 4:00 p.m.

Jinlong Wu
Department of Mechanical Engineering
The University of Texas at Austin

The subject of this seminar is the propagation of sound in a circular duct with locally reactive acoustical lining, and in which a sheared mean fluid flow exists. Previous theoretical investigations of this problem were based on numerical solutions. Following a brief review of earlier work, an analytical solution of the parallel shear flow wave equation will be presented for the case in which the mean flow Mach number is small and the viscous boundary layer is thin. These conditions are commonly assumed in studies of sound propagation in pipes with low velocity, turbulent air flow. Results are presented for a variety of wall impedances, flow profiles, and acoustic modes of propagation, and comparisons are made with reported numerical results. A method for including finite amplitude effects will be outlined.

The Combustive Sound Source

Friday, November 19, 1993 4:00 p.m.

Preston Wilson
Applied Research Laboratories
and
Department of Mechanical Engineering
The University of Texas at Austin

This presentation describes a new type of underwater sound source, the Combustive Sound Source (CSS). The gas mixture produced by electrolysis of water is captured in a combustion chamber and ignited with a spark, producing a high intensity, low frequency pulse. Rayleigh-Willis theory is discussed in relation to high-speed films of the bubble produced by CSS. The motion of the bubble is found to be related to the acoustic output in a classic manner. Two experiments were conducted to compare the first bubble period in the CSS pressure signature with the prediction of the Rayleigh-Willis equation. Pressure signatures were recorded for various bubble volumes and depths. Empirical equations are presented which predict the first bubble period for three different situations. Finally, several other factors that affect the acoustic output of the CSS, such as the shape of the combustion chamber, the ignition source, and the oxidizer, are discussed.

Improvement of Dynamic Driver Performance Using an Amplifier with Negative Output Impedance

Friday, December 3, 1993 4:00 p.m.

Tom Kite
Department of Electrical Engineering
The University of Texas at Austin

When driven by a normal power amplifier, a dynamic driver in a sealed enclosure exhibits the frequency response of a resonant, second-order, high-pass filter, and has an underdamped transient response. A power amplifier with negative output impedance is used to improve the frequency response of the system around resonance, and to critically damp the driver. 1970s funk music will be used to show the improvement in bass extension obtainable with this technique.