The Underwater Sounds from the Impact of Drops in Superfluid 4He

Friday, January 26, 2001 4:00 p.m.

Antonios Apostolou
Graduate Program in Acoustics
Pennsylvania State University, and Schlumberger Oilfield Services
http://www.acs.psu.edu
http://www.psu.edu
http://www.slb.com/oilfield/index.cfm?id=id4638

When a drop of a liquid impacts onto a liquid surface, a crater is formed and the cavity dynamics that follow determine whether or not a bubble will be entrained. The entrainment of an air bubble following the impact of a raindrop onto the sea provides the predominant mechanism for the production of the underwater noise from rain. Experiments in water have indicated one particular entrainment region in a dimensionless parameter-space. This talk describes an ongoing research effort to study the phenomenon on a more fundamental basis using, instead of water, the pure and highly characterized liquid helium. The impact of liquid helium drops onto a liquid helium surface is monitored by employing acoustic and optical techniques. Bubble entrainment in superfluid 4He, as well as the transition to non-entrainment, are observed, and the collected data indicate a new entrainment region. In addition, high-speed images of the crater motion reveal novel crater dynamics for the non-entrainment case.

Inversion of Biot Parameters for Water Saturated Sand

Friday, February 2, 2001 4:00 p.m.

Dr. Nicholas P. Chotiros
Applied Research Laboratories
The University of Texas at Austin
http://www.arlut.utexas.edu

An inversion of the Biot model using measured acoustic properties suggests a modification of the Biot-Stoll equations as they apply to the propagation of sound in water saturated sand. The Biot model of sound propagation in porous media, as formulated by Stoll, requires 13 input parameters to generate acoustic properties. The input parameters may be divided into three groups according to the accuracy with which they are known. The first group contains tabulated physical constants, the second group is less precisely known, and the third group is simply not measurable. An inversion procedure was devised to estimate the immeasurable group from simple acoustic measurements—reflection loss, compressional and shear wave speeds, and attenuations. Although the inversion process is nonlinear, in practice it is well behaved and converges quite rapidly to a unique solution. The issue of imprecisely known parameter values was handled in a probabilistic manner. The inversion results for water saturated sand, based on published laboratory and in-situ measurements, show a definite incompatibility between the physical and acoustical measurements. In an attempt to find a solution, two possible hypotheses are put forward: (1) the inclusion of some proportion of the pore fluid within the frame, and (2) the coefficient of fluid content as an independent variable. The latter proved to be the only plausible solution, requiring one change in the Stoll formulae and an additional independent parameter. It implies that the solid frame cannot be

considered to be uniformly elastic.

An Application of Acoustic Design in Telecommunications

Friday, February 9, 2001 4:00 p.m.

Dr. Kenneth Huang and Andrew Morrison
Motorola Network Systems
Ft. Worth, Texas
http://www.motorola.com

Initially telecommunications equipment was concealed in maintenance areas or rooftops. The miniaturization of electronics and the growth of the cellular market has permitted base station equipment to be located nearer to human observers (e.g., utility poles, sides of residences, and business offices). This in turn has created increased concern about acoustic noise generated by the cellular telecommunications base station equipment, which is one subject that will be addressed in this seminar. We shall also provide an overview of electronic packaging trends, the future of cellular telephony, the cellular base station environment, and examples of Motorola products.

Boundary Element Modeling of the External Human Auditory System

Friday, February 16, 2001 4:00 p.m.

Dr. Timothy Walsh
Institute for Computational Engineering and Sciences
The University of Texas at Austin
http://www.ticam.utexas.edu

Within the context of the external auditory system, a benchmark that is used by acousticians and audiologists is the head-related transfer function (HRTF). The HRTF is used in understanding the localization process, deducing resonance modes of the ear canal, as well as in the design of hearing aids and virtual acoustic simulators. It is normally measured experimentally in an anechoic chamber using a rotating frame. Although numerical simulations provide an alternative approach for generating the HRTF, their application presents several challenges to the numerical analyst, including accurate representation of the geometry, mesh adaptivity for boundary element methods, and parallelization. These issues will be addressed briefly in this talk. Following the discussion of the numerical algorithms, the results of the numerical computation of the HRTF will be presented and compared with experimental data from the literature. The quarter-wave resonance modes and the corresponding surface pressure distributions of the concha and ear canal will be deduced from the numerical HRTF and compared with experimental observations from the literature. The numerical results show the negligible effect that the ear canal has on spatial cues, and thus on the localization process as well. Computations on meshes with and without the ear canal will give some insight into the acoustical effect of terminating the canal with a hearing aid, or some other acoustical device. Initially telecommunications equipment was concealed in maintenance areas or rooftops. The miniaturization of electronics and the growth of the cellular market has permitted base station equipment to be located nearer to human observers (e.g., utility poles, sides of residences, and business offices). This in turn has created increased concern about acoustic noise generated by the cellular telecommunications base station equipment, which is one subject that will be addressed in this seminar. We shall also provide an overview of electronic packaging trends, the future of cellular telephony, the cellular base station environment, and examples of Motorola products.

Three-Dimensional Ultrasound Imaging with Blazed Acoustic Arrays and Time-Frequency Beamforming

Friday, February 23, 2001 4:00 p.m.

Lee Thompson
Applied Research Laboratories
The University of Texas at Austin
http://www.arlut.utexas.edu

A novel solution to reducing hardware requirements for 3D acoustic imaging is described. The solution is based on high-resolution imaging sonar miniaturization research currently underway at ARL:UT. The research combines techniques used in radar, optics, and time-frequency signal processing to significantly reduce the cost, size, and power of acoustic imaging systems. Frequency-scanning radar involves the use of frequency to steer the radar beam. This technique typically employs delay lines in antenna array transmitters that introduce phase shifts which permit frequency to determine the steering angle of the main beam, and it is referred to as angular frequency dispersion. In optics, angular frequency dispersion is accomplished with prisms and gratings. If one combines techniques similar to the frequency-scanning techniques of radar with blazed acoustic array (grating) design techniques from optics and time-frequency signal analysis techniques, a single-channel acoustic imaging system can be created. This imaging system requires only a single hardware channel (one stave) from the array to generate a 2D image, because the blazed array effectively multiplexes the beam signals into separate frequency channels. Consequently, the beamformer for such a blazed receiver signal can be designed around a time-frequency distribution, such as a short-time Fourier transform. If this technique is used orthogonal to conventional array design and beamforming techniques, a 3D acoustic imaging system can be designed around the same number of hardware channels required for a conventional 2D system.

Adventures in Acoustical Consulting: 1985-2001

Friday, March 2, 2001 4:00 p.m.

David Nelson
Nelson Acoustical Engineering, Inc.
Elgin, Texas
http://www.nelsonacoustical.com

This seminar will chronicle the journey of one UT acoustics graduate from the well-ordered heights of academia into the maelstrom of real-world acoustics and noise control. The discussion will include numerous short case histories, anecdotal examples and observations from 15+ years of professional experience, with an emphasis on the “black art” of noise control at the source. Recent projects of interest include low-noise design for experimental packages flying on the International Space Station, noise and vibration control for mixed-use buildings with large shock and vibration sources, a multi-channel

acoustical data acquisition system, and noise control for a 125-acre industrial plant. Along the way we'll encounter such noise control challenges as squeaking valves, howling pipes, shrieking saw blades, and noisy fans, all of which were solved at the source without recourse to conventional "noise control materials." The talk will reveal the complex, multi-disciplinary, and practical aspects of this work and will provide an overview of what it's really like to successfully practice noise control engineering.

Application of Multitone Stimulus to Modeling and Analysis of Air-Related Nonlinear Distortion in Sound Systems

Friday, March 23, 2001 4:00 p.m.

Dr. Alexander Voishvillo
Cerwin-Vega, Inc.
Simi Valley, California
http://www.cerwin-vega.com

Multitone stimulus is used in identification of weakly nonlinear systems and for assessment of nonlinearity in sound and broadcasting equipment. Spectral and statistical characteristics of multitone signals resemble those of musical signals, and the response to multitone stimulus yields more useful information about nonlinearity than conventional measurements of harmonic and two-tone intermodulation distortion. Previous work has demonstrated that strong harmonic and intermodulation distortion accompanies the propagation of waves radiated by large horn arrays. Our group has recently developed propagation models for 1D multitone waves in horns. The modeling is based on numerical solution of implicit equations describing distorted waveforms. It takes into account linear propagation of the fundamental tones and their reflections from the mouth, and the nonlinear, reflection-free propagation of distortion products. Further research may include radiation of multitone waves by a complex source, substitution of multitone stimulus by a musical signal to provide listening tests, and auralization of propagation nonlinearity in horns and in freely propagating waves radiated by complex sources such as large horn arrays. The propagation model already provides auralization of nonlinear distortion in 1D waves of finite amplitude. Data obtained from modeling may be used to build Volterra models of nonlinear propagation. Such models may lead to signal processing solutions to minimize distortion in propagating waves.

Gas Dynamics, Mass Transfer, and Chemical Reactions in Violently Collapsing Bubbles

Friday, March 30, 2001 4:00 p.m.

Dr. Brian Storey
Franklin W. Olin Cockrell School of Engineering
Needham, Massachusetts
http://www.olin.edu

In sonochemistry, sonoluminescence, and shock-wave lithotripsy, micron-size bubbles are subjected to intense ultrasound fields. Often, bubbles in these applications experience a long, slow expansion before undergoing a collapse so violent that the contents of the bubble can become sufficiently hot to emit a brief flash of light. Because of the extreme nonlinearity of the bubble oscillations, excess water vapor is trapped in the bubble during this violent collapse. The water is prevented from exiting the bubble by the relatively slow rate of mass diffusion and non-equilibrium condensation. Consideration of the trapped vapor is crucial to understanding the physical processes occurring during the collapse. Through the use of computational fluid dynamics, the flow, transport and chemistry occurring in the interior of the bubble were modeled in great detail. With these computational models as a basis, the important physical processes can be understood and more practical, reduced models can be developed. The models provide reasonable predictions of experimental sonochemistry yields, the stability threshold of sonoluminescence experiments, and the rather extreme behavior of bubbles in shock-wave lithotripsy.

Single Bubble Sonoluminescence

Wednesday, April 4, 2001 4:00 p.m.

Dr. Lawrence A. Crum
Center for Industrial and Medical Ultrasound
Applied Physics Laboratory
University of Washington
http://www.apl.washington.edu/EmployeeProfiles/RPD/crum.html
http://www.apl.washington.edu/

When an acoustic wave of moderate pressure amplitude is propagated through an aqueous liquid, light emissions can be observed. This conversion of mechanical energy into electromagnetic energy is called Sonoluminescence (SL) and represents an energy amplification per molecule of over eleven orders of magnitude! Recently, we made the discovery that a single, stable gas bubble, acoustically levitated in a liquid, can emit optical emissions each cycle for an unlimited period of time. Presumably, the oscillations of the bubble cause the gas in the interior to be heated to incandescent temperatures during the compression portion of the cycle. Furthermore, some recent experimental evidence indicates that the lifetime of the optical pulse is less than 50 picoseconds, and that the temperature in the interior of the bubble can exceed 100,000 K. Most conventional explanations for the phenomenon are unsatisfying and it is likely that some rather unusual physics is occurring. The best explanation, at the moment, is that a shock wave is created in the gas which is then elevated to high temperatures by inertial confinement. If shock waves are the mechanism for SL emission, then optimization of the process could lead to extraordinary physics, including nuclear fusion. This phenomenon has captured the imagination of a wide variety of individuals, from serious scientists to movie producers—the movie Chain Reaction was (loosely) based upon SL. A brief review of this intriguing phenomenon will be presented as well as my frustrating attempts to explain its potential (and its limitations) to the news media and the general public.

Medical Application of Acoustics

Thursday, April 5, 2001 4:00 p.m.

Dr. Lawrence A. Crum
Center for Industrial and Medical Ultrasound
Applied Physics Laboratory
University of Washington
http://www.apl.washington.edu/EmployeeProfiles/RPD/crum.html
http://www.apl.washington.edu

Medical ultrasound technology is experiencing a rebirth as methods and applications extend beyond current diagnostic imaging to include novel therapeutic and surgical uses. These applications broadly include: Tissue ablation, cautery, lipoplasty, and hemostasis via targeted non-invasive thermal deposition; site-specific and ultrasound mediated drug activity; novel imaging approaches using ultrasound contrast agents and signal processing; extra-corporeal lithotripsy; and enhancement of natural physiological functions such as wound healing and tissue regeneration. This general lecture will address some of the basic scientific questions and future challenges in the areas listed above. We shall particularly emphasize the use of High Intensity Focused Ultrasound (HIFU) in the treatment of hemorrhagic trauma and related pathological conditions, especially in organs which are difficult to treat using conventional medical and surgical techniques. Direct applications include combat casualty care, as well as many civilian uses in non-invasive or minimally invasive trauma management, bloodless surgery, and ultrasound-mediated drug therapy. We shall also explore imaging and simulation techniques associated with treatment, targeting, and monitoring the effects of HIFU therapy. Finally, we shall describe our efforts to successfully transition the scientific developments in our laboratory to commercial products, and thus will describe our attempts to start new companies or work with existing ones to implement technology transfer.

Acoustical Design of Studios and Theaters

Friday, April 20, 2001 4:00 p.m.

Mark Genfan
Acoustic Spaces
Martindale, Texas
http://www.acousticspaces.com

Acoustic Spaces is involved mainly in the design and installation of recording studios, video facilities and other high-end technical facilities. We also design and provide consultation services for public theaters, home theaters, and various commercial clients. This seminar will describe the backgrounds and training of personnel within the company. The design process will be discussed, particularly the interaction with clients to ensure that acoustical and practical, ergonomic considerations are properly combined. Emphasis will be given to software and other tools used in the design process, as well as acoustical properties, materials and devices. Current trends will be described, as well as recent technological advances used in studios and theaters, both public and home, and how they impact acoustical design considerations. Examples of AutoCAD drawings and acoustical analysis of rooms and spaces will be shown. Coordination with architects and builders will be addressed, as well as budgets and other

business aspects of acoustical consulting.

Airblast from TWA Flight 800

Tuesday, May 1, 2001 4:00 p.m.

Jack W. Reed
JWR, Inc.
Albuquerque, New Mexico
http://www.nmia.com/~jwreed

Nearly 300 FBI witness interviews reported a bang or bangs associated with this accident off Long Island in 1996. Most attention, however, was devoted to visual sightings of a described variety of streaks and flashes, which were first interpreted as rocket motor trails. This led to investigations which concentrated on recovery and study of aircraft debris and geometric resolution of sighting descriptions. No clear evidence of any missile attack was ever found, so efforts turned toward some other on-board source for this disaster. Various experiments concluded that a spark in the “empty” central fuel tank could have caused the initiating explosion, and that a spark could have been generated from the fuel meter wiring. This became the final conclusion of the National Transportation Safety Board (NTSB) Final Report, issued in August 2000, although couched in many caveats of uncertainty. There has been controversy over NTSB treatment of witness visual reports, but very little discussion of the reported noises. Early estimates showed that one ton of TNT was probably needed for an explosion to shake houses and cause some of the reported bangs. However, for the NTSB Report, NASA-Langley was tasked to look into this and concluded that the noise could have been caused by just 20 lb of TNT (a reasonable equivalent for fuel tank fume detonation). Analyses presented at this seminar should lead to rejection of this conclusion.

On Light Emission of Sonoluminescing Bubbles

Friday, September 21, 2001 4:00 p.m.

Dominik Hammer
Department of Physics
The University of Texas at Austin
http://www.ph.utexas.edu

Sonoluminescence is the emission of light from tiny gas bubbles in water that expand and contract under the influence of an external pressure wave. Results from experiments investigating this phenomenon are shown along with our attempts at understanding it in terms of well-known physics. Our focus is on the light emitting mechanisms which are treated in the framework of a hydrodynamic-chemical description of the oscillating bubble: The time varying water vapor content of the bubble is taken into account as well as chemical reactions of the water (i.e., dissociation) and ionization of the bubble gas due to quasi-adiabatic heating of the bubble. The light emission is shown to be mostly due to electron-neutral atom and electron-ion bremsstrahlung as well as recombination radiation. In relatively cool bubbles, radiative attachment to oxygen and hydrogen atoms also contributes to the emission. Preliminary results on the emission of OH signatures of very dim bubbles are presented.

Inversion for Source and Environmental Parameters in the Shallow Ocean Using a Rotated Coordinates Technique

Friday, September 28, 2001 4:00 p.m.

Dr. Tracianne B. Neilsen
Applied Research Laboratories
The University of Texas at Austin
http://www.arlut.utexas.edu

The problem of localizing and tracking a source in the shallow ocean is often complicated by uncertainty in the environmental parameters. A method is presented that uses a rotated coordinates technique [M. D. Collins and L. Fishman, J. Acoust. Soc. Am. {98}, 1637-1644 (1995)] in simulated annealing to invert for both the source and the environmental parameters. The rotated coordinates technique not only aids in the inversion process, but it also indicates the coupling of the source and environmental parameters and the relative sensitivities of the cost function to changes in the various parameters. The information obtained from the rotated coordinates provides insights into how the inversion problem can be effectively decoupled. The cost function minimized in the inversion algorithm is model-data cross-phone spectra summed coherently over phone pairs, frequency, and time sequence. The results of applying this inversion method to simulated array data to obtain source and environmental parameters are presented. In addition, inversion results for environmental parameters when Gaussian white noise is added to the simulated data are given. [Work supported by ONR.]

Acoustical Design Considerations in an Unusual High School Auditorium

Friday, October 5, 2001 4:00 p.m.

Richard E. Boner
Boner Associates, LLC

Over the past generation, the design of high school auditoria has evolved from simple, acoustically mediocre shoe-box style, to a variety of designs. Among these are narrow fan-shapes, wide fan-shapes, and experimental designs. This talk focuses on yet another design, where the school is treated to a more European type house, complete with multiple balconies and adjustable acoustics. Acoustical design considerations are discussed, including architectural, noise control, and electro-acoustic.

Acoustical Requirements for Personal Computers

Friday, October 12, 2001 4:00 p.m.

Jeff DeMoss and John Parker
Dell Computer Corp.
http://www.dell.com

A company marketing personal computers may find it necessary to provide customers with relevant acoustical characteristics of the product. Traditional noise emission metrics, sound power and sound pressure, have normally been used. More customers are beginning to make purchasing decisions based on the sound quality of information technology products rather than the traditional metrics. A more relevant means of measuring customer preference is needed to aid product designers. Innovations in technology (lower cost, processing speed, ease of use) have made sound quality tools more available and should be explored as a means of assessing customer preference for information technology products.

Cavitation in Lithotripsy and High Intensity Focused Ultrasound Therapy

Friday, October 19, 2001 4:00 p.m.

Dr. Mike Bailey
Center for Industrial and Medical Ultrasound (CIMU)
Applied Physics Laboratory
University of Washington

Shock Wave Lithotripsy (SWL), which uses focused shock waves to break up kidney stones, is a common and successful clinical procedure. However, tissue injury also results in most if not all treatments. Cavitation (bubble action) likely plays a role in both breakup and tissue damage. High intensity focused ultrasound (HIFU) is used to thermally necrose tumors or cauterize bleeds. Treatment area control and image guidance are two challenges that have slowed clinical acceptance. Bubbles likely play a role in distorting the lesion shape but may be very helpful in ultrasound guidance. At CIMU we are interested in better understanding cavitation's role in lithotripsy and HIFU and controlling it to improve both procedures. Some of our efforts are discussed in this seminar. First, the in vivo results of work begun at UT and ARL are reported. Manipulation of the phasing but not the amplitude of a lithotripsy pulse reduced tissue injury and cavitation. Second, overpressure (elevated static pressure) reduced tissue injury, probably by suppressing cavitation. Our hypothesis is that at atmospheric pressure, bubbles created by one lithotripter pulse act as cavitation nuclei for subsequent pulses and that overpressure accelerates the dissolution of the bubbles. Numerical calculations and experimental results support the hypothesis. Third, in HIFU, lesion shape distortion, believed caused by scattering from bubbles created thermally or acoustically, is reduced by overpressure. However, bubbles can be used to image and to monitor the treated area. Last, some results of cavitation detection in vivo during lithotripsy and of the application of HIFU in vivo are reported.

Acoustics and Signal Processing Research at Applied Research Laboratories

Friday, October 26, 2001 4:00 p.m.

Dr. Karl B. Fisher and Dr. Rich Gramann
Applied Research Laboratories
The University of Texas at Austin
http://www.arlut.utexas.edu

Applied Research Laboratories (ARL), University of Texas at Austin , has been a leader in acoustic research since its founding as the Defense Research Laboratory immediately after World War II. ARL research in acoustics has traditionally focused on Department of Defense applications with an emphasis on Navy active and passive sonar systems. Naval sonar systems are used in a variety of applications that include surveillance, anti-submarine warfare, and mine and swimmer detection. The design and optimization of these sonar systems requires a thorough understanding of the complex acoustic propagation in the ocean coupled with sophisticated signal and information processing algorithms. Over the years, ARL's acoustic research programs have extended beyond naval applications and presently include such efforts as automated land vehicle detection/classification systems based on combined acoustic and seismic signatures, autonomous acoustic systems for drug interdiction, and industrial applications. ARL is the largest organized research unit at UT Austin and consists of five research laboratories. An overview of current ARL research in acoustics is presented in this seminar.

Mechanically Imploded Light Bulbs as Acoustic Sources

Friday, November 2, 2001 4:00 p.m.

Dr. David Grant
Applied Research Laboratories
The University of Texas at Austin
http://www.arlut.utexas.edu

Light bulbs make handy acoustic impulse sources for underwater research. They are inexpensive, readily available anywhere, and simple to use, requiring no special training or heavy deployment equipment. Their acoustical properties are easily characterized in terms of their mechanical characteristics. Their acoustical levels and their waveforms are not a threat to marine life. Because of these characteristics, light bulb sources are being used more and more in underwater acoustics research. Knowledge of their acoustical properties is important for acoustics test planning and test data analysis. In this work we have set out to measure the acoustical properties of only a few types of bulbs. What makes this work unique is that we have taken many samples of each type of bulb so as to characterize the variability. The measurements have been done under carefully controlled conditions so that the acoustical levels are known to a high degree of accuracy. We also measured relevant physical characteristics of the bulbs to allow comparison with theoretical treatments. To date, only a cursory comparison of the data with theory has been done. Future work will involve a more thorough comparison with theory to see how well the acoustical properties can be predicted from physical properties.

Nonlinear Acoustics in Water-Saturated Sand

Friday, November 16, 2001 4:00 p.m.

Dr. Nicholas P. Chotiros
Applied Research Laboratories
The University of Texas at Austin
http://www.arlut.utexas.edu

A variety of basic acoustical experiments were performed to test the linearity of sound waves in dry and water-saturated sand. The finite-amplitude and phase comparison methods were used to observe nonlinearity characteristics in sand and glass bead samples. It was found that uniform glass bead samples were less linear than sand. The fact that variations in sound speed could be induced by changing the external frame stress suggests that the acoustic energy may be carried by random force chains. On the other hand, for water-saturated samples, which showed a greater degree of linearity and little variability, the force chain model may not be applicable. Measurement of the nonlinearity of water saturated sand was not straightforward. Experimental results will be shown.

Particle Image Velocimetry and Temperature Measurements in Thermoacoustic Stacks

Wednesday, November 28, 2001 4:00 p.m.

Dr. Philippe Blanc-Benon
Ecole Centrale de Lyon
Lyon, France

The knowledge of temperature and flow fields in the microchannels and at the edges of the stack plates becomes an increasingly important issue in the design of heat exchangers for thermoacoustic engines. On these topics we have conducted experiments in a resonant standing wave thermoacoustic refrigerator model. First, we present experimental data obtained using Particle Image Velocimetry: velocity profiles across the microchannels, 2D velocity maps including a zoom for the edges of the stack, and vorticity fields calculated with a criterion based on a normalized angular momentum. Second, using a linear array made of miniature thermocouples, we measured the build-up of the temperature gradient along the stack for different oscillating flow conditions. In particular the effect of the plate spacing is illustrated. Finally, comparisons are made with theoretical models and numerical simulations recently published in the literature.

Scattering of Sound by a Core Vortex: Numerical Simulations Using a Wide-Angle Parabolic Equation

Friday, November 30, 2001 4:00 p.m.

Dr. Philippe Blanc-Benon
Ecole Centrale de Lyon
Lyon, France

The generation and scattering of sound by flow inhomogeneities such as vortices are basic problems which have received much attention in the efforts to develop methods to detect strength and location of noise sources. Recent experimental studies have demonstrated that acoustic scattering can serve as an efficient (direct and nonintrusive)probe of the vorticity field for the characterization of turbulent flows. In 1978 Candel presented the results of a numerical study based on a standard parabolic equation in which the sound speed variations are included through an effective sound speed c eff = c 0+ V x, where the x axis gives the direction of propagation of the acoustic wave. However, the effective sound speed model does not include the effects of the perpendicular components of the velocity field, and the importance of these components increases with the angle of propagation. A wide angle parabolic equation (WAPE) has recently been proposed in order to increase the angular validity of the parabolic approximation. This equation called MW-WAPE takes into account mean velocity effects up to second order in Mach number. To estimate the validity of this new parabolic equation, we considered a configuration with both strong gradient and high Mach number. Our results are compared to a reference solution obtained by solving the linearized Euler equations. The MW-WAPE solutions are in good agreement with the reference solutions. This parabolic equation gives accurate results up to M=0.5, whereas the standard parabolic equation using an effective sound speed failed to give good results above M=0.2.