SAVIAC
Shock and Vibration Information Analysis Center
Current Awareness
December 2004
Happy Holidays!

Introduction to Air Blast Measurements

Part IV: Getting the Signal Down the Cable

Editor's Note: This is the fourth article in a series high-lighting one of this year's featured commercial agencies, PCB Piezotronics.

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In Parts I, II and III of this series we provided an understanding of the air blast environment and the operation of transducers intended to measure it. We went on to describe how to mount these transducers to optimize their dynamic response and how to validate the resultant signal output from the transducers. These considerations alone don't guarantee success unless we are able to transmit the signal down the cable with fidelity. Since, as mentioned previously, 100s or 1000s of feet of cable can be involved, signal distortion can occur.

For the following discussion, the consideration of a lossless transmission line (one whose resistance is ignored) will suffice. A voltage signal v going down the line is a function of both space (z) and time (t), i.e., $v = v(z,t)$. Its equation can be given as[6]:

$$\partial^2 v(z,t)/\partial z^2 = lc\left[\partial^2 v(z,t)/\partial t^2\right] \quad (3)$$

where l and c are the line inductance and capacitance per unit length. This is the classical wave equation that governs many other physical phenomena such as stress wave transmission in a bar and acoustic wave transmission in an organ pipe. By analogy, $1/\sqrt{lc}$ has a dimension of velocity.

Many facilities where air-blast testing is performed also measure and record data from strain gages and other bridge type circuits. Therefore, 4-wire shielded cable is typically used. A representative instrumentation cable could be: Belden[7] non-paired #82418, 4-conductor, 18 AWG, fluorinated ethylene propylene insulation, Beldfoid shielded, with an inductance of 0.15 µH/foot and a conductor-to-conductor capacitance of 30 pF/foot. Using the above equation ($1/\sqrt{lc}$) to calculate the propagation velocity for this cable results in 0.47 x 10^9 ft./sec. or roughly 0.5 the speed of light.

The characteristic impedance for a lossless line is expressed as $\sqrt{l/c}$, which for the preceding cable can be calculated to be 70.7 ohms. If the cable is terminated properly ($\sqrt{l/c}$ = 70.7 ohms), there will be no reflections at high frequencies. However, if the cable is not terminated properly (e.g., if it operates directly into a high impedance amplifier (typically R >= 1MΩ)), reflections can occur. The first reflection will occur at a frequency (f) corresponding to a wavelength (λ) equal to four (4) times the cable length. As an example, arbitrarily pick the highest signal frequency of interest to be 100,000 Hz. The corresponding wavelength is:

$$\lambda f = \text{propagation velocity or}$$
$$\lambda = (0.47 \times 10^9 \text{ ft./sec.})/(1 \times 10^5 \text{ Hz.}) = 4700 \text{ ft.} \quad (4)$$

Thus, a cable length of (4700/4) or 1175 feet will result in oscillations at a frequency of 100,000 Hz. In addition, signal fidelity can only be maintained to approximately 20,000 Hz, which is one-fifth the frequency of oscillation.

Figure 12 below shows an obtained, experimental frequency response for 400 feet of a 4-conductor shielded

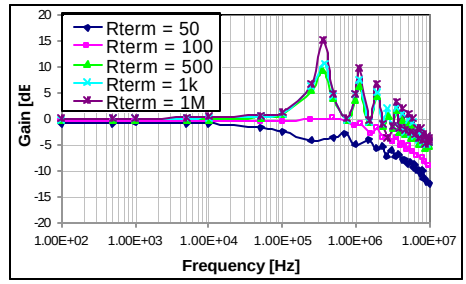

Figure 12: Response of Belden 22 AWG 4-Conductor Cable as a Function of Termination

Belden instrumentation cable of #22 AWG. Note the resonant frequency at 330,000 Hz for the infinite load (R = 1M Ω). If we calculate the fundamental wavelength for this cable, and again use 0.47 x 10^9 ft./sec., which is an approximation for this cable, we get λ = (0.47 x 10^9 ft./sec.)/(3.3 x 10^5 Hz.) = 1,424 ft. or a cable length of 1,424/4 = 356 feet, which agrees reasonably well with the known value of 400 feet. Thus, when high frequencies and long cable runs are involved, cable termination and impedance matching is very important. Note the improvement in constant or "flat" frequency response with the R = 100Ω termination.

IEPE or ICP® sensors have an additional limitation associated with their high frequency response. For very long cable runs, one has to assure that there is adequate current to drive the cable capacitance. If the time varying current $i(t)$ supplied to the cable is $i(t)$ = (I)sin(2π ft), then at low frequencies:

$$v(t) = (1/C)\int i(t)dt = [(I/2\pi fC)\cos(2\pi ft)] \quad (5)$$

Here, C is the total cable capacitance. It can be seen that the magnitude of the measured voltage is inversely proportional to C, which is itself propor-

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Free Winter Shock & Vibration Seminar

SAVIAC invites you to attend a FREE seminar on Shock & Vibration. The course will be held in February, 2005 at a to-be-determined site in conjunction with the SAVIAC Winter Technical Advisory Group (TAG) Meeting. SAVIAC and the featured experts in their disciplines have organized this seminar to introduce you to the SAVIAC community, while providing a valuable educational experience. A parallel half day session on Homeland Defense is being considered.

Agenda

8:00 - 8:30	Registration & Continental Breakfast	
8:30 - 9:00	Introduction to SAVIAC	Joel Leifer, SAVIAC
9:00 - 9:30	MIL-S-901 Requirements/Approval Process	Kurt Hartsough, NSWC/CD
9:30 - 10:00	TBD	TBD
10:00 - 10:15	Break	
10:15 - 10:45	Overview of Hazard Assessment Testing (HAT) per MIL-STD-2105	Jamie Howell, NSWC/Dahlgren
10:45 - 11:15	Data Archiving Recommended Practice	Dan Worth, NASA Goddard
11:15 - 11:45	Zero offsets in Accelerometer data: Causes and Corrections	Tim Edwards, Sandia
12:00 - 1:00	Lunch (no host)	
1:00 - 1:30	SAVIAC Mentor Program	Bob Krezel
1:30 - 2:00	Navy Hydrocode Development Efforts for Underwater Explosion Effects	Greg Harris, NSWC/IH
2:00 - 2:30	Aluminized Explosive Modeling	Eric Rinehart, DTRA
2:30 - 3:00	TBD	TBD
3:00 - 3:15	Break	
3:15 - 3:45	Lithium Battery Environmental Testing	Allen Parkes, NSWC/Crane
3:45 - 4:15	Joint Education Initiative	TBD
4:15 - 4:45	Shock Isolation	Chris Merrill
4:45 - 5:00	Wrap-up & Questions	All

Please forward this invitation to anyone you know who may be interested in attending this program.

The seminar is free, but you must register to attend as space is limited. Please RSVP to Lauren Yancey, (703) 892-0060 or lauren.yancey@saviac.org to assure your space and note packet. SAVIAC reserves the right to substitute topics and/or instructors when necessary. This schedule is subject to change. For more information about SAVIAC please visit our website at www.saviac.org.

Intro Air Blast, con't from Page 1

tional to the length of the cable, so the measured voltage goes down with increasing cable length. The same inverse relationship holds for frequency. Conversely, the voltage is directly proportional to the current. The nomograph in Figure 13 plots these relationships.

To use this nomograph, let's take the previous example of the Belden #82418 cable with capacitance of 30 pf/foot. If we encountered 1,000 feet of cable (which is a moderate amount for air-blast testing) back to a recording station, total capacitance would be 30,000 pF. If 100,000 Hz response and a maximum of 1 volt of signal level are required, the nomograph provides a value of $V/(i_c\text{-}1)$ of 0.055. Note i_c is in milliamp and 1 is subtracted to account for the current required to power the ICP electronics. Substituting, $1/(i_c\text{-}1) = 0.055$ would result in a required supply current of 19.2 ma. 20 ma tends to be the maximum supply current for ICP circuits. If 5 volts maximum signal were required,

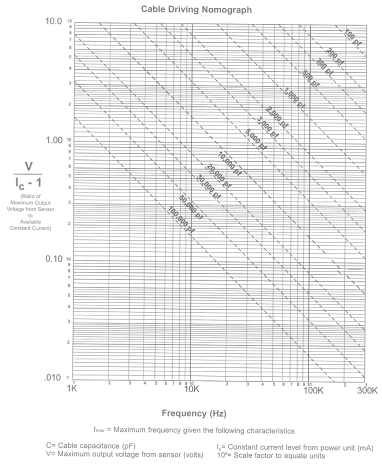

Figure 13: Nomograph Showing Effect of Frequency and Cable Capacitance On ICP ® Signal Output

and the maximum supply current were provided, $V/(i_c\text{-}1) = 5/(20\text{-}1) = 0.263$. Entering the table where 0.263 on the abscissa intersects 30,000 pF yields an upper frequency limit of about 21,000 Hz. While proper cable termination (impedance matching) is likely not required for the 21,000-Hz signal, it definitely would be for the 100,000-Hz signal. When possible, the cable frequency response should be checked by driving it through the same type ICP® circuit as will be used in application. As cables shorten, and frequencies lower, the cable termination becomes increasingly less important.

6. Matick, Richard L., Transmission Lines for Digital and Communication Networks, IEEE Press, pp.31-35, 1995.
7. Belden CDT Inc., St. Louis, Missouri

Explosion Effects and Structural Design for Blast

A 2-day Training Course
At the Embassy Suites Hotel
St. Louis Airport
February 28 and March 1, 2005

Instructors: Dr. Sam A. Kiger, PE and Dr. Stan Woodson, PE

Engineers have an opportunity to improve their skills in understanding explosion effects and designing facilities that are safer to occupants by understanding and minimizing the effects of explosive detonations on structures. Architects and builders will also benefit by appreciating the impact of explosive design decisions early in the process. All new government buildings now require some level of blast resistant design and this training will specifically address those requirements.

Course Description:

This course will focus on the fundamentals of explosion effects, determining blast loads on structures, computing structural response to blast loads, and the design and retrofit of structures to resist blast effects. The emphasis will be on terrorist threats from vehicle bombs, but the fundamental concepts can be applied to other explosive scenarios. Currently available software and publications for blast effects and design guidance will be discussed and demonstrated. Much of the design guidance and software is restricted distribution to government agencies and their contractors, however specific information on how to use and obtain the software will be covered in the course. The participant will gain an understanding of how to compute blast loads on a structure, how to compute structural response to blast loading, and practical methods for designing and retrofitting structures to resist blast effects. Participants will be provided with a complete set of class notes. A general background in structural analysis and structural design will be assumed.

Primary Topics Include:

Explosion Effects, Loads on Structures, Behavior of Structural Elements, Structural Dynamics, Response Calculations (approximate methods and computer codes), and Retrofit Techniques.

Course Location:
The course will be held at the Embassy Suites Hotel, St. Louis Airport. For reservations call 1-800-EMBASSY (1-800-362-2779) and ask for the “Blast Design Training” rate of $102 per night. A full breakfast is included in the room rate.

Course Registration:
Registration Fee is $895.00 (Includes lunch each day). Your payment, in full, must accompany your registration form.

Course Refund Policy:
Refund of registration fee, less $50 to cover processing costs, are available upon cancellation notice by the registrant. Notification will be by fax, dated and signed by the person registered, to Dr. Sam Kiger at 573-882-4784. The refund will be by check mailed, within 30 days, to the registrant at the address requested on the fax. No refund will be allowed after five working days before the day the course begins. In the event the course is canceled a full refund will be paid to the individual at the address given at the time of registration. Questions may be directed to Dr. Sam Kiger at kigers@missouri.edu or by calling 573-882-3285.

More information about the instructors, the course, and accommodations can be found at http://blastdesigntraining.com. Professional engineers will get continuing education credit of 15 PDH's for the course. On-line registration is available and will ensure your seat is reserved. Questions regarding content and appropriateness can be obtained by contacting Dr. Sam Kiger at 573-882-3285, KigerS@missouri.edu or Stan Woodson at 601-636-4429, WoodsonEng@direcway.com.

Announcement for International Short Course on

Response of Marine Structures to Underwater Explosions

March 22-25, 2005
Monterey Beach Hotel
2600 Sand Dunes Drive, Monterey California 93940

Course Lecturers:

Professor Thomas L. Geers
Dept. of Mechanical Engineering
University of Colorado
Boulder, Colorado 80309

Dr. Young S. Shin
Shock and Vibration Research
Monterey, California 93940

Course Objective & Overview

Course Objective: The purpose of this course is to provide engineers, scientists, and naval architects a discriminating review of underwater explosion phenomena, structural response analysis, fluid-structure interaction, shock spectrum concept, and shock-induced vibration analysis of shipboard equipment.

Course Overview:

1. UNDERWATER EXPLOSION PHENOMENA: Sequence of Underwater Explosion Events, Hydrodynamic Relations, Underwater Acoustic Waves, Air-Water Interface, Shock Wave Parameters, Bubble Behavior and Bubble-Pulse Loading, Bulk and Local Cavitation, Scaling
2. ELEMENTS OF STRUCTURAL DYNAMICS: Analytical Dynamics, Classical Linear Oscillator, Two-Degree-of-Freedom System, Finite Element Discretization and Modelling, Finite Difference Time Integration
3. FLUID-STRUCTURE INTERACTION: Athwartship Response of Submarine, Vertical Response of Surface Ship, Submerged Plate Oscillator
4. DAA-BASED ANALYSIS: Submerged Spherical Shell, FE/BE Fluid-Structure Interaction, USA-DYNA, USA-NASTRAN, etc.
5. FLUID VOLUME DISCRETIZATION: Fluid Cavitation, Validation of Computer Codes
6. MODELLING AND SHOCK SIMULATION: Three Dimensional Ship Shock Analysis, Modeling and Approaches
7. SHOCK QUALIFICATION OF SHIPBOARD EQUIPMENT BY DESIGN ANALYSIS: Shock Spectra, Normal Mode Analysis, Response of a Multi-DOF System to Shock Motion
8. DYNAMIC DESIGN ANALYSIS WORKSHOP: Dynamic Design Analysis Method (DDAM), DDAM Step-by-step Analysis Procedure, Design Criteria of Shipboard Equipment Using DDAM
9. APPLICATION TO SHIPBOARD EQUIPMENT USING DESIGN ANALYSIS: Application Problems

Course Organization

REGISTRATION FEE

The following registration fee includes the cost of all sessions, coffee breaks, and the course notes.
$ 1,620 --- if paid by February 22, 2005.
$ 1,800 --- if paid after that date.

ACCOMMODATION

A block of rooms has been reserved at special rates for short course attendees at the Monterey Beach Hotel (Rates $75 single & 95 double). To qualify for these special rates, you must mention that you are attending the "Shock 05 Seminar". Attendees should contact the hotel directly to make reservations. The rooms at the special rates will only be held until February 22, 2005.

COURSE LOCATION

The course will be conducted in Monterey, California, USA;
Monterey Beach Hotel
2600 Sand Dunes Drive, Monterey, California 93940
Phone: (800) 242-8627 or (831) 394-3321
Fax: (831) 393-1912
Email: montereybeachresort.com

FOR FURTHER INFORMATION, CONTACT:

Shock and Vibration Research
10150 Blue Larkspur Lane
Monterey, California 93940, USA
Phone/Fax (831) 375-4999, Cell: (831) 277-7117
Email: undex05@sbcglobal.net

Announcement for International Short Course on

APPLICATIONS OF LS-DYNA/USA CODE TO SHIP- SHOCK MODELING AND SIMULATION

March 28 - 30, 2005
Monterey Beach Hotel
2600 Sand Dunes Drive, Monterey California 93940

Course Lecturers:

Dr. John A. DeRuntz, Jr.
Unique Software Applications
Colorado Springs, CO 80906

Dr. Young S. Shin
Shock and Vibration Research
Monterey, California 93940

Course Objective & Overview

Course Objective: The purpose of this course is to provide engineers the applications of coupled LS-DYNA/USA code to ship-shock modeling and simulation.

Course Overview:

1. THE PHYSICS OF UNDERWATER SHOCK
2. FLUID-STRUCTURE INTERACTION: Exact Formulations, Doubly Asymptotic Approximations, Interaction Equations, Augmentation For Unconditional Stability
3. FLUID MASS MATRIX DEVELOPMENT: Potential Flow Boundary Element Method, Model Symmetries And Fluid Boundaries, Bottom Effects Model, Surface Of Revolution Models, Fluid Boundary Modes, Rigid Body Added Mass And Rotational Inertia Coefficients
4. CAVITATING FLUID ANALYSIS
5. OVERVIEW OF THE UNDERWATER SHOCK ANALYSIS CODE
6. USING THE USA CODE: Processor Functions, Structural Modeling Preliminaries, Wet Surface Mesh from Structural Model, User Options
7. USING THE USA-CFA CODE: External and/or Internal Fluid Problems, Radiation Boundary Options, LS-DYNA Usage, Fluid Volume Modeling and Stability, Transient Response Analysis and Stability
8. INCIDENT SHOCK WAVE SPECIFICATION: Scaling Laws, Tabular Inputs, Exponential Waves And Double Decay, Built In Explosives, Features
9. BUBBLE PULSE SPECIFICATION: Physical Basis, Hicks Bubble Model, Theory, Units, Options, Features
10. COMBINED SHOCK-BUBBLE SPECIFICATION: Physical Basis, Geers-Hunter Bubble Model
11. Using USA/LS-DYNA: USA/LS-DYNA Processors, Execution of USA/LS-DYNA, Wet-Surface Modeling, LS-DYNA Time Step Control, Hydrostatics, Damping, Resilient Mounts, LS-DYNA Fluid Volume Elements, USA/LS-DYNA Sample Problems
12. OTHER TOPICS: Problem Areas Where More Work Is Needed, Selected USA/LS-DYNA Sample Problems
13. LS-DYNA CODE FOR SHIP SHOCK MODELING: Capabilities, Features and Limitations, Software Organization, Ship Structure and Surrounding Fluid Modeling, Radiation Fluid Boundary, Ship System Damping Modeling & Error Correlation Factors
14. LS-DYNA AND USA INPUT DECK SETUP: Ship Structures and Surrounding Fluid, Ship System Damping, Radiation Boundary and Shock Analysis Geometry
15. SHIP SHOCK MODELING & SIMULATION PROBLEMS: 1D, 2D and 3D Model and Analysis

Course Organization

REGISTRATION FEE

The registration fee is $1,250 which includes the cost of all sessions, coffee breaks, and the course notes. Early registration is suggested because enrollment is limited. Please send us email or phone call requesting registration form.

ACCOMMODATION

A block of rooms has been reserved at special rates for short course attendees at the Monterey Beach Hotel (Rates $75 garden side). To qualify for these special rates, you must mention that you are attending the "Shock-05 Seminar". Attendees should contact the hotel directly to make reservations. The rooms at the special rates will only be held until 4 weeks before class starts.

COURSE LOCATION

The course will be conducted in Monterey, California, USA;
Monterey Beach Hotel (email: montereybeachresort.com)
2600 Sand Dunes Drive, Monterey, California 93940
Phone: (800) 242-8627 or (831) 394-3321
Fax: (831) 393-1912

FOR FURTHER INFORMATION, CONTACT:

Shock and Vibration Research
10150 Blue Larkspur Lane
Monterey, California 93940, USA
Phone/Fax (831) 375-4999, Cell: (831) 277-7117
Email: undex05@sbcglobal.net

Insert PDF of 2005 Call for Papers

Conference & Short Course Announcements

Practical Shock Analysis & Design Short Course
MFPT Society
February 28-March 4, 2005
Bremerton, WA

This course will provide a comprehensive treatment of practical shock design and analysis with special emphasis on applications related to the design of ship structures and equipment for shock loads produced by underwater explosions. Participants in this course will have an opportunity to increase their knowledge and understanding of the analytical and experimental tools that are available for shock design and qualification particularly with respect to requirements that are imposed for shipboard equipment. The lectures will provide a basic review of vibration and shock theory and will present the analytical and experimental methodology in the context of particular design applications. Analytical lectures will emphasize the physical significance of the results. Examples and case histories will be used as illustrations of design approaches; workshop problems that involve class participation will be used to advantage throughout the course. Class members will be encouraged to propose real design problems. The instructors will provide guidance for solutions or the problems may be used as class exercises. Although this course is aimed primarily at shock design applications on ships, the analysis and design techniques presented are equally applicable to problems related to design for seismic loads or blast induced ground shock. For more information and to download the registration form, visit http://www.saviac.org/Shock%20Course.htm.

DEFENSE 2005
AIAA
March 21-22, 2005
Washington, DC

Following the tumultuous events of the past few years, the United States is now redefining its place in a dynamic global environment that has challenged established ideas and traditional thinking. The future depends more than ever on close cooperation and strategic partnerships, as well as on our ability to define flexible capabilities and refine processes that deliver them in innovative ways. The AIAA Defense conference historically engages the nation's economic and national security policy experts, military leaders, senior Executive branch, Congressional members, and senior industry executives in discussion on defense policy, acquisition, and reform. With BAE SYSTEMS as this year's lead host, AIAA Defense 2005 will follow this same format—but with a timely and critical focus on the strategic environment of coalition warfare and creating global partnerships. A team of high-profile speakers from the top levels of Congress, the Pentagon, and industry powerhouses is being assembled by our expert executive steering committee. The team will join international industry leaders and operational experts to identify serious issues, suggest ways to nurture crucial partnerships, and provide guidance for the Administration in setting the necessary defense priorities and agendas for 2005 and beyond. Panels will be formed to answer tough questions about current defense acquisition and operational needs and industrial and global policy. Attendees can expect to hear candid answers on provocative issues and proposed innovative solutions for meeting future demands.

You don't want to miss this critical and comprehensive executive forum--AIAA Defense 2005! For more information or to register nline please visit http://www.aiaa.org/content.cfm?pageid=230&lumeetingid=1154.

INDUSTRY NEWS

Industrial Pressure Sensors Detect Pulsations, Surges, and Leaks

Depew, NY - Series 121 industrial, dynamic ICP® pressure sensors from the Pressure Division of PCB Piezotronics, Inc. detect very small pressure fluctuations in the presence of high static background pressures. Typical applications include the detection of dynamic pulsations, surges, leaks, water hammer, cavitation, and spikes in liquid delivery systems, pumps, and compressors.

Sensors contain built-in microelectronic circuitry to deliver a clean, voltage output signal, and are offered in full-scale ranges from 100 to 5,000 psi (700 to 35,000 kPa). Units feature hermetically-sealed, stainless steel construction and a 1/4 NPT or straight metric M14 mounting thread, and are available with a 2-pin MIL connector or an integral, submersible cable assembly. Electrical case isolation provides shielding from electromagnetic fields and eliminates ground loop problems.

For additional information, contact the Pressure Division of PCB Piezotronics, Inc. toll-free at 888-684-0011 (in the U.S. and Canada) or 716-684-0001; fax 716-686-9129; email: pressure@pcb.com, or visit PCB's web site at www.pcb.com.

LMS Provides Caterpillar Inc. with Solutions for Noise and Vibration Engineering

Leuven, Belgium - LMS International announced today that LMS will provide Caterpillar with LMS Virtual.Lab and LMS Test.Lab for Noise and Vibration engineering. The LMS solutions will be used to optimize the vibration comfort and noise performance of new designs, from the early virtual prototype stages up to the final prototype validation.

Competitive pressure continuously forces off-highway manufacturing companies to optimize the noise and vibration performance of their products and to pro-actively respond to changing customer requirements and ever-stricter legislation.

In off-highway engineering, the role of noise and vibration testing is no longer limited to the qualification and optimization of physical prototypes in the late development stages. Using LMS Virtual.Lab Noise and Vibration, engineering teams analyze the correlation between Finite Element (FE) models and test models, and improve the accuracy of FE models. In addition, LMS Virtual.Lab Noise and Vibration assists them in building hybrid simulation models, combining FE models and test-derived models of components and subsystems. Overall, LMS Virtual.Lab Noise and Vibration supports the accurate simulation and efficient optimization of a design's noise and vibration performance before committing to virtual prototype testing. For additional information in the US please contact Sarah Zajas, LMS North America, Tel 248 952 5664, sarah.zajas@lmsna.com.

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In the December 2004 Current Awareness Newsletter

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