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ACOUSTICS AND VIBRATION SINCE 1948

- Research and Development
- Design of Low-Vibration Facilities
- Transportation, Environmental, Industrial Noise & Vibration
- Product Noise Control and Sound Quality
- Remote Monitoring of Vibration and Noise
- Audiovisual System Design, IT Infrastructure and Planning



Acentech's staff of more than 50 engineers, scientists and consultants brings more than 62 years of experience to projects across a broad spectrum of acoustics and vibration for government, military and commercial clients.

Research and Development

Acentech is actively involved in research and development through the SBIR and STTR programs. The following are a sample of the projects that we have recently completed.



Acoustic Cloaking with Metamaterials: U.S. Navy (Ongoing)

Acoustic cloaking refers to a method to hide underwater objects by diverting sound waves around them. A metamaterial cloak surrounding an object absorbs waves falling onto the cloak and guides them around the object where they emerge on the opposite side as though the object was not there, rendering it invisible. In this Phase II project, working with Kansas State University and Cuming Corp., Acentech has developed a design for an acoustic cloak for a submerged UUV-sized cylindrical object using simple mechanical elements assembled in a novel way to form a metamaterial.

Plans call for fabrication and demonstration of a pre-prototype cloak in the Phase II option.

Objective Diagnostic Tool for Tinnitus in Military Populations: U.S. Army

Hearing loss and tinnitus are common unfortunate results of military service. However, there is presently no objective test or series of tests that can provide a reliable diagnosis or quantitative assessment of tinnitus. This type of evaluation would be indispensible in diagnosis and as a metric for efficacious treatment. Working with Ceres Biotechnology of Richmond, VA, in an Army Phase I SBIR, Acentech will develop and demonstrate a



quantitative evaluation device that can be used in a manner similar to standard audiometric methods.



Noise Reduction for Dive Helmets: US Navy

Helmeted divers are exposed to hazardous levels of noise generated within the helmet by respiration, and also by exposure to external noise sources. This noise can interfere with communications, add stress to missions and significantly limit dive durations as the levels typically exceed the allowable daily 'noise doses' established by OSHA and the Navy. Despite precautions taken, Navy and commercial divers are at risk for developing long term hearing loss. In this project, Acentech is developing an

experimentally-driven "noise audit" to determine the primary sources of helmet respiration noise in order to develop effective helmet quieting design modifications. In addition, an external treatment will be designed to reduce the transmission of exterior sound (e.g., from tools or sonar) into a helmet.

Design of Transducers for Underwater Communications and Hearing Protection: U.S. Navy

The goals of this project were to improve communications between divers and the dive ship or barge, maintain stealth, and protect the hearing of military and commercial divers working in noisy environments such as underwater salvage and hull cleaning. The primary deliverable was a novel in-ear



communications earphone for use by SCUBA divers, which allows for pressure equalization as dive depth changes.





Active Noise Control Earplug for Carrier Flight Deck: U.S. Air Force

The noise levels on aircraft carrier flight decks can approach 150 dBA, an environment where personnel must work, communicate, and avoid danger. The attenuation required to avoid hearing loss cannot be achieved using conventional hearing protection devices, and commercially available active noise reduction (ANR) earmuffs are not able to lessen the severity of these very high sound levels. Achieving high levels of attenuation requires the use of

a deep insert active noise reduction earplug together with an external earmuff. The driver (loudspeaker) for the active system therefore has to fit within the ear canal, and be able to produce sound pressure levels at the eardrum high enough (approximately 130 dB) to effectively cancel the noise at that location.

Since commercially available hearing aid transducers could not meet these requirements, Acentech developed system models for the ANR earplug and determined that, out of five initial designs considered, two novel "push-pull" designs had the potential for meeting these and other system requirements. The first of these designs is based on a dual-unit electromagnetic balanced armature design, and the other is based on an electrostatic design utilizing two pairs of single crystal Lead Magnesium Niobate-Lead Titanate (PMN-PT) plates arranged in bimorph fashion. We partnered with a hearing aid manufacturer to fabricate pre-prototype versions of these two transducer types, which were then



tested in both open- and closed-loop situations. Further evaluations indicated that the push-pull balanced armature design was likely to be best suited for the current ANR earplug application. Ten working prototypes of this design were then fabricated, tested and delivered to the Air Force. We were able to obtain typical sound pressure levels of between 125 and 130 dB from these prototypes.



Building Interrogation and Machinery Location and Identification: U.S. Army Corps of Engineers

Imagine this scenario: a squad of soldiers comes upon a building that may contain power generation, manufacturing, or communications equipment. They would like to know what that equipment might be, and where it is (in the basement, on an upper floor, etc.) prior to entering the building. The Building Interrogation and Machinery Location and Identification (BIMLI) project, supported by the U.S. Army, consisted of a series of studies that culminated in a vibration-based prototype system that detects, classifies and locates a machinery source within a building.

Machinery in a building shakes the floor and walls; sound is radiated away from the building. The frequencies of vibration and their relative strength and phase relationships depend both on the type of machinery and the building characteristics. Acentech's RH Lyon Division developed a way of sensing the vibrations made by internal machinery at the exterior of a building, and then processing these vibration signals to both identify and locate the machinery.

The system we developed makes use of vibration signals that are wirelessly transmitted to a base notebook computer from a triangular 3element accelerometer array designed for mounting on an exterior wall surface. Detection and identification are first performed using a custom developed classification approach based on an extensive library of machine vibration signatures. If an operating machine is detected, then localization is performed to determine an overall direction of vibrational energy flow based on phase delays calculated between the "horizontal" and "vertical" sensor pairs - an approach that takes into account distortions imposed onto the vibration signals by wall and floor



constructions. Moving the sensor array to a second position on the wall enables the source to be located via triangularization of the two calculated wave directions.





Acoustic Mapping of Tunnels and Caves: U.S. Army Corps of Engineers

This research project attempts to extend a technique — originally developed for medical use to determine the geometry of lung and nasal passages — to larger systems such as caves, tunnels, and piping systems. The technique involves injecting infrasound (low frequency sound) into the cave or tunnel and measuring the incident and reflected sound waves using two spaced microphones

placed just inside the entrance. Computer algorithms, developed as part of this project, unravel the sound signals and produce a map of the cross sectional area that lies beyond the entrance. A field prototype, consisting of a loudspeaker capable of producing infrasound, the two microphone array, and the signal processing was field tested in an underground tunnel system that is part of a military urban training facility. This portable acoustics system will allow military personnel to determine the shape and extent of a cave or tunnel without having to enter it. Potential commercial applications of this mapping technique include tunnels and piping networks in cities, where this acoustical system could be used to determine the extent of forgotten tunnel systems or possible constrictions due to tunnel failures or other obstructions.



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SCIF Acoustic Certification

Sensitive Compartmentalized Information Facilities (SCIFs) are critical for security in government, military and private sector operations. Working with a government agency, Acentech developed a portable system to measure the acoustic isolation effectiveness of a SCIF based on the principles of architectural acoustics. The acoustic measurements are combined with similar electromagnetic data to assess the overall security of the space.



Design of Low-Vibration Facilities

Acentech's consultants have advised on the design of numerous low-vibration facilities for the military, universities and industry.

NRL Nanoscience Research Laboratory

NRL's Nanoscience Research Laboratory is a state-of-the-art facility intended for leading-edge research to support the Navy's mission. As such, it needs to meet extremely stringent vibration and noise requirements. The building includes a 5000 square foot class 100 clean room and twelve specialized laboratory spaces designed to accommodate ultra sensitive instruments. The specifications called for noise levels to be limited to NC-25 and floor vibration velocities not to exceed 125 micro-inches per second. The facility's location, at approximately 2900 ft east of the extended centerline of runway 01/18 of Reagan National Airport presented a unique challenge, in view of the frequent aircraft departures on this runway. The requirement to achieve the prescribed noise limit without interruption resulted in adoption of a windowless "box-in-box" design, with the most sensitive spaces located in the inner core. Meeting of the noise limits required shielding this inner core by multiple partition walls with high acoustic transmission loss, providing acoustical doors, and implementing special provisions to limit noise intrusions via the air handling systems, as well as controlling the air velocities in the duct systems.



LISE at Harvard University

Harvard's new Laboratory for Interdisciplinary Science and Engineering (LISE) is a state of the art nanotechnology research facility. The building contains a number of vibration sensitive labs, a Class 10 clean room and ten ultra-low vibration labs. Acentech provided a range of services for this project including architectural acoustics, mechanical system noise and vibration control and structural dynamics (footfall-induced vibrations on above-grade floors).

One of the unique and forward thinking aspects of the design was a series of ten rooms in the basement designed for ultra-low vibration

environments. The rooms were designed with double concrete block walls for sound isolation and each room contained a massive inertia block that could be utilized by the researchers if needed. At present there is no need for the blocks to be fitted with vibration isolation systems, but this capability has been included in the design in the event that it is needed in the future.

Subsequent to base building completion, Acentech was involved in the fit-out of user-specific labs. This included the design of the audiovisual systems for conference rooms which include presentation systems and audio conferencing capabilities.



MIT Brain and Cognitive Sciences Center

A rail line carrying 2-3 heavy freight trains per day passes through MIT's Brain and Cognitive Sciences Center. The Institute was concerned that vibrations from the trains might affect sensitive equipment.

Acentech measured the vibrations from freight trains and performed transfer mobility tests to determine ground vibration propagation at the site. We measured the vibrations from 36 freight trains over two-weeks. We recorded vibrations from six sensors (3 surface sensors and 3 subsurface sensors at the bottom of boreholes up to 115 feet deep). We used transfer functions between the sensors and the applied force to calibrate a numerical model of the ground which in turn was used to evaluate

the vibration isolation potential of various foundation schemes and building constructions. Acentech used the rail-induced vibration data to determine the required vibration isolation to protect the sensitive equipment in the building and to assess the effects of rail vibration on the building's researchers.



Transportation, Environmental, Industrial Noise and Vibration

Acentech's consultants work on transportation, environmental and industrial noise and vibration projects across the US and abroad. Our work includes power plants, construction projects involving noise control, noise reduction, vibration, transportation systems, industrial sites and more.



F-22 Acceptance Testing

Acentech assessed the environmental noise impacts for the subsonic and supersonic acceptance tests of the F-22 fighter after final assembly at Dobbins AFB in Marietta, Georgia. The analysis included the addition of 591 operations per year, preflight, and ground run-up tests.

Acentech provided the noise and sonic boom analysis for the project; developed a methodology for assessing the noise impacts based on existing noise levels; recommended applicable noise criteria; modeled the noise from subsonic and supersonic F-22 aircraft flights; and prepared the noise sections for the

environmental assessment. Acentech also updated the modeling associated with the existing AICUZ.



Stonegate Quarry

A quarry developer planned to create a granite quarry on a site surrounded by a residential community in southwestern New Hampshire. Acentech evaluated the potential noise impact of quarrying operations on the surrounding communities. We used the CADNA noise mapping program to predict this impact. Acentech utilized CADNA to predict and assesses outdoor noise levels from multiple industrial and transportation sources, taking into account terrain and other objects that affect sound emission and

propagation. Our staff monitored noise levels from the planned equipment at a different site and acoustically superimposed the information onto a map of the proposed quarry site. This computer modeling predicted an impact that would be avoided by moving operations to a topographically shielded location. Our findings were presented at a local planning board hearing as part of the developer's application process.



New Hampshire International Speedway

The Town of Loudon, New Hampshire retained Acentech to evaluate the effect on community noise of the planned addition of 9,000 seats to the 75,000-seat facility of the New Hampshire International Speedway. This racetrack facility is New England's stop on the tour for major NASCAR, motorcycle, and Indy car racing events. Communities more than 2 miles from the facility have been affected by noise generated by the racing events. Also affected is an historic tourist community in Canterbury, New Hampshire nearly 2 miles from the facility. Acentech monitored noise levels at the

facility and in the surrounding communities for major events. From these data, we are developed a model of community noise levels for each type of racing event and providing recommendations for practical mitigation measures with the proposed expansion of the facility



Product Noise Control and Sound Quality

The noise produced by a product, or even the quality of that noise as interpreted by consumers, can have an impact on a product's ability to succeed in the marketplace. Acentech's consultants help our clients by providing design guidelines to minimize sound by analyzing design choices and evaluating and/or specifying layouts and components. Many clients also consider the quality of a product's sound, not just its loudness. Through statistically designed jury studies, we measure the perception of the product based on its sound. We correlate that perception to those components of the product that contributes to its sound. Then we offer concrete methods to modify the sound quality of products, moving it into the realm of greater acceptability.



Vacuum Pump Diagnostic Noise Audit

To reduce overall noise, the individual noise source must be quantified and noise mitigation must address the loudest source(s) first. The process of determining the contributions from each noise source is called a "noise audit".

In the case of a vacuum pump there are several noise sources to consider, for example the motor, pump mechanism, fans, exhaust flow pulsations, and vibration-induced radiation from the casings. One technique we used to

measure the contribution from the various sources, called the window method, involved silencing all individual sources on the device, for instance, with foam-lined lead covers, as pictured. We uncovered one source at a time to measure its contribution independently of the other sources. The result was a rank ordering of noise sources which identified and quantified the source(s). The manufacturer then focused noise reduction efforts on the appropriate components and understood how much of a reduction could be expected.



Small Utility Tractor

Some products are generally loud and are expected to be so. In this case, while the tractor operator may be concerned about hearing loss or the disturbance to neighbors, he or she also likes to feel a sense of power and function when using it.

The tractor manufacturer wanted to identify and determine the impact and value of various possible sound quality improvements to their line of small

farm and utility tractors, including those that might be associated with adding a cab enclosure. To accomplish this, Acentech structured the project into three main parts consisting of (1) a focus group study to assess what aspects of tractor sound were important to the target consumer population, (2) a separate sound quality jury study to quantify how changes in the sounds of various tractor components and mechanisms affected user perceptions of tractor power, functionality and quality/reliability, and (3) development of a statistical model for relating objective sound quality metrics to subjective consumer judgments. Competitive products were also included in the evaluations.

Results from one type of jury study (using the technique of magnitude estimation) were used to formulate a regression equation that related changes in the sounds of five different tractor components to juror ratings. Such information revealed, for example, that engine noise and cooling fan noise had the largest impact on the perception of power, while hydraulic-related sounds and engine noise had the largest impact on perceived quality and reliability. Furthermore, since these relationships were quantified, design tradeoffs could also be quantified. Another type of jury study used the method of paired comparisons to determine consumer preference rankings of various tractors based on their sounds, and to determine the average additional dollar value that customers would be willing to pay for the increased sound isolation provided by an enclosed cab.



Remote Monitoring of Vibration and Noise

Construction noise and vibration can be a significant concern to operators of sensitive facilities that are located near the construction site. Buildings that house highly sensitive equipment and/or operations (such as hospitals, research facilities, and performing arts venues) can be adversely affected by noise and vibration at levels far below those traditionally associated with building damage. Sufficiently severe vibrations can cause significant disturbance or, in extreme cases, cause the facility to shutdown vibration-sensitive operations. In these instances, typical construction monitoring programs are generally not sensitive enough to measure low-level vibrations that are vital to these situations.

Acentech's remote monitoring systems provide administrators, managers, contractors and researchers with real-time notification and continuous access to critical vibration and noise information. Using an internet connection, monitors can not only be viewed, controlled and downloaded remotely, but can send email and text alarm messages when pre-set limits are exceeded. These capabilities allow interested parties to anticipate problems, mitigate activities, schedule operations and document potential impacts.



Construction Vibration Monitoring at Sensitive Facilities in Gaithersburg, MD

Our client was responsible for the construction of a new 308,000 square-foot, seven story laboratory building in close proximity to several active bio-pharmaceutical research and production facilities, including a vivarium. The company wanted to continue operations during construction, if at all possible.

Acentech worked with the contractor and the owner to develop a measurement plan for documenting both baseline and constructionrelated vibrations throughout the facility. Prior to construction, Acentech obtained one-week samples of ambient vibrations at nine selected

locations, including laboratories, vivariums, and clean bio-manufacturing areas. The baseline measurements were used to set threshold levels to be used during construction. Our systems were left in place to monitor the construction-related vibrations continuously over a five-month period. Using an internet connection, Acentech remotely controlled and downloaded data from each of the systems, and prepared weekly vibration reports.



Wind Turbine Noise at Vinalhaven Island, ME

Vinalhaven Island, 12 miles off Maine's coast, is home to the largest community-based wind power project on the east coast of the US. Three GE wind turbines, each rated at 1.5 MWe, will harness the island's wind resource to generate more than 11,000 megawatt-hours of electricity per year, which will meet the electric power needs of the local communities while also cutting electric bills. Working together with the project manager and community during planning and licensing, Acentech measured both local wind speeds and baseline pre-development ambient sound levels, calculated expected sound levels from the new turbines, and submitted noise impact assessment reports. Acentech also provided continuous measurements and analysis of the turbines' operating sound levels.



Audiovisual System Design, IT Infrastructure and Planning

Whether a performing arts center, conference room or a campus-wide video distribution network, Acentech's consultants have the experience and knowledge to design state-of-the-art systems that are cost-effective and user-friendly. Acentech has been providing knowledgeable sound system consulting and design for more than 50 years. Architects, building owners, facility operators and equipment manufacturers turn to Acentech for the latest system technology and solutions.

Acentech employs an integrated approach to technology, providing comprehensive IT consulting services to document, design, integrate and coordinate the physical space requirements, power loads, heat loads, copper cabling, fiber optic cabling, and wireless networking requirements for voice, data, audio-visual, multimedia and Internet applications.



Harvard Business School

The 3 year renovation of Aldrich Hall began with the complete renovation of two "mock-up" classrooms as a test for architectural, technology and acoustics integration. The project included the renovation of 17 classrooms and the addition of a new headend facility in Hawes Hall for the Business College. Each phase incorporated a complete "blow-out" and rebuild of each designated renovation area while the rest of the building remained operational in a June to September time frame.



Video Production Studio at Hasbro Corporation

The Hasbro toy company created a 2,800 SF video production studio within one of the existing facilities at their corporate headquarters in Pawtucket, RI. The studio is used to produce promotional pieces and in-house training videos. Acentech worked with Hasbro and their architect, Bargmann Hendrie + Archetype, to define the acoustical design criteria which included sound isolation goals generated by specific noise-sensitive adjacencies, studio finishes aimed towards optimizing speech intelligibility, and very quiet background noise levels to optimize audio recording.





Fenway Health

Fenway Health completed construction of its new state-of-the-art 10-story 100,000 square-foot health facility and research center in 2010. Acentech designed the audiovisual and IT systems for the new building. Audiovisual systems serve several conference rooms, a 3-segment divisible meeting space, as well as a tiered 176-seat auditorium. The systems include digital signage, complex display systems, videoconferencing, distance learning, and room scheduling capabilities. We designed the IT system to support these technological spaces, as well as a VoIP phone system, building wide data network, and Wi-Fi connectivity. Taking advantage of the data network allows the AV systems to be interconnected and provides the Fenway staff with a single point of management, in addition to supporting the various pieces of medical equipment. We designed the high-tech systems to be simple to use and operate by the staff and visiting lecturers. Each room includes a touch screen control panel located just outside the room so that users can schedule the room and check activities

occurring within an occupied room locally.

