Acoustic Emission Local Area Monitoring System

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ABSTRACT

The use of Acoustic Emission (AE) for testing and monitoring steel bridges, has been of interest to the Federal Highway Administration (FHwA) and the Nondestructive Testing (NDT) industry. An FHwA contract (DTFH-61-90-C-00049) was completed in 1994 resulting in a set of guidelines for AE bridge monitoring as well as a management video informing state Departments Of Transportation of the value of AE bridge monitoring.

The work completed in 1994 (after performing a variety of AE tests on 15 different bridges), gave rise to an idea based on monitoring known and suspect defect areas. In this scenario, AE sensors are mounted on different types of bridge structures and in some kind of strategic arrangement surrounding the defect and/or area of interest. Detection of AE takes place as the bridge is loaded as a result of normal traffic flow or, in some special cases, from overloading with specially prepared vehicles. The greatest benefit identified for AE, was with local area monitoring.

In 1995, the FHwA and Physical Acoustics Corporation (PAC) entered into a cooperative agreement, under contract (DTFH61-95-X-00026), to design and fabricate a prototype, portable AE monitoring system. This AE system, better known as the Local Area Monitor (LAM), has been completed and evaluated in the field on two different bridges. This paper focuses on the development and evaluation of this system and will discuss the intended application for steel bridges with known and suspect defects.

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BACKGROUND

The concept of local area monitoring with AE comes from PAC's experience with bridge engineers and many FHwA contracts. This technique concentrates on monitoring small areas on a bridge where there is concern about the status of a known or suspected defect. The technique utilizes a limited number of AE channels and takes advantage of the structural loading resulting from normal traffic patterns. Applications suitable for local area monitoring include:

- Determining if a pre-existing or detected crack is active
- Monitoring of retrofits
- Monitoring of highly stressed areas to determine structural integrity (usually a weld or connection point
- Monitoring a suspected area that cannot be visually inspected or inspected by any other NDT means (box beams are an example)

In 1990 PAC was contracted by the FHwA (Contract DTFH-61-90-C-00049) to: (1) demonstrate AE on bridges around the USA; (2) develop a management video, informing the state Departments of Transportation on the value of AE in bridge monitoring; and (3) develop guidelines for AE bridge monitoring. These goals were met with the monitoring of at least 15 bridges, development of a very informative 20 minute video and the generation of a comprehensive document called "Acoustic Emission For Bridge Inspection, Application Guidelines" [1]. This document contains detailed information on the following: (1)Principles of AE Technology in regards to bridges; (2) The role of AE Testing in bridge inspection; (3)Wave propagation in bridge components: (4) Equipment setup and operation on bridge components; and (5) Examples of bridge inspections. Similar work has been performed in the United Kingdom by Physical Acoustics Limited and the University of Wales/Cardiff [2] and the U.S.A. by the Virginia Transportation Research Council [3].

In the 15 cases mentioned above, PAC was asked to monitor "known defect" areas and give the customer more information about the activity level of these defects. This experience led us to recommend to the FHwA the development of a suitable AE system for local area monitoring. In 1995, FHwA and Physical Acoustics Corporation entered a cooperative agreement (DTFH61-95-X-00026) for the "Design and Fabrication of a Proto-type Portable Acoustic Emission (AE Monitoring System)". Details of the prototype AE system being developed under this contract follow.

INTRODUCTION

The Local Area Monitor (LAM) shown in Figure 1, is a powerful, rugged and modular 8 channel Acoustic Emission (AE) System developed for monitoring bridge structures. The instrument has several key features which will be described below.

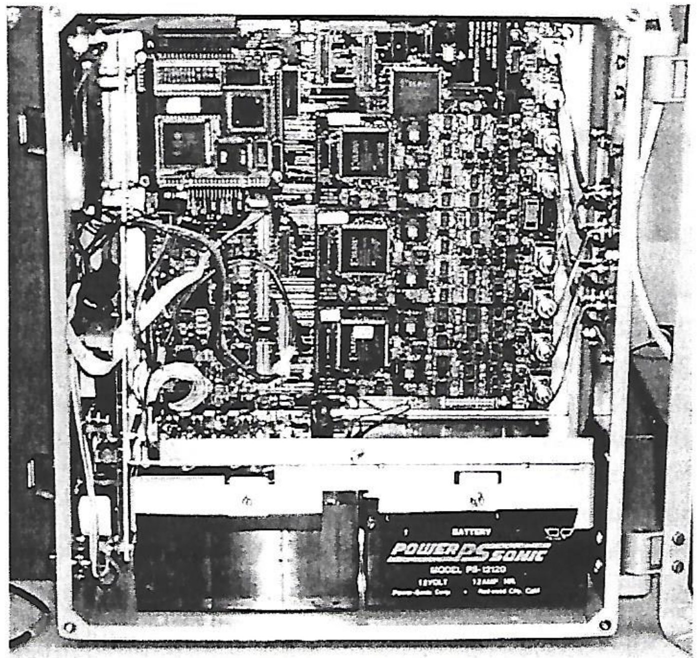

Figure 1. LAM instrument in NEMA 4 enclosure.

The LAM is a modular instrument with options for being configured with 2, 4, 6 or 8 AE data channels modular (2, 4, 6 or 8). The selection of number of channels will be dictated by the size or the area to monitor and the complexity of the bridge structure. If desired, these data channels can be used as guard sensors when it is necessary to discriminate between defect emissions and extraneous noise coming from outside the suspect defect area.

AE waveforms can be digitized and stored, when selected as an option, along with the traditional AE signal features. Signals from other sensors (such as strain gauges and accelerometers) can be recorded through the use of high speed parametric inputs (up to 4) for comparison with the AE data. This is can be very useful when trying to discriminate between defect emissions and traffic noise. The LAM also has the ability, through low speed parametric inputs, to record other environmental parametric inputs (up to 6 channels) for monitoring temperature, wind speed, system voltage and temperature, strain, etc.

In situations were no power is available, the LAM has the ability to run on its own internal battery power (standard) with one backup battery (optional). If required, it can also run off of solar power and external batteries, use 12-16 Volt DC power or AC voltage.

By choosing a particular configuration, the instrument can be used as a stand alone laboratory fatigue experiment instrument, a short term flaw condition monitor on a bridge (with an operator present), a long term bridge integrity monitor (with remote operator control through the use of a modem) or a "big bang" incipient failure detection monitor. Besides the instrument shown in Figure 1, the user may want to have available a PC with monitor, keyboard and mouse.

This modular design lends itself well to light weight, easy handling in the field, since the user only installs the precise features needed for any particular job. Cable lengths are minimized since the instrument is mounted at a location close to the defect site. Permanent attachment to the structure (to avoid theft) is possible although temporary attachment is possible using magnetic clamps.

A user typically can "tailor" the instrument to both his/her needs and budgets by purchasing only the modules they will use. The lowest cost base configuration will permit short term local area monitoring jobs under complete battery power. Modules and software options to expand the system's capabilities are available to upgrade the system for applications above the base configuration.

PAC has designed the LAM into an environmentally sealed NEMA 4 case, thus avoiding the reliability risks associated with the field use of a powerful computerized instrument. This enclosure provides protection against moisture and high temperatures that can potential destroy the electronic circuitry. This design also includes shock protection to protect the system during shipping and handling.

The standard LAM interface is a serial port connected to a users notebook or desktop computer where the program residing in the user computer controls the system and performs data analysis. Optionally, there are several other interfaces available including extending the serial port cable using wired RS-485 Multidrop techniques (where multiple LAM's can be connected to a single cable), Wireless modems to eliminate the wiring between the LAM and user altogether, a wired or Cellular telephone interface for long distance remote control and monitoring, and a Laboratory configuration where the user only needs to add computer keyboard, mouse and CRT monitor to communicate and control the LAM.

SYSTEM OPERATION

Setup

Data sensors (1 and 2 in this example) are typically mounted near the defect as shown in Figure 2. These sensors can be surrounded by guard sensors (3 and 8 in this example) that allow differentiating and separating defect emissions from the extraneous noise associated with traffic and structural movement. Strain gauges and other sensors are mounted nearby so that their signals can be recorded along

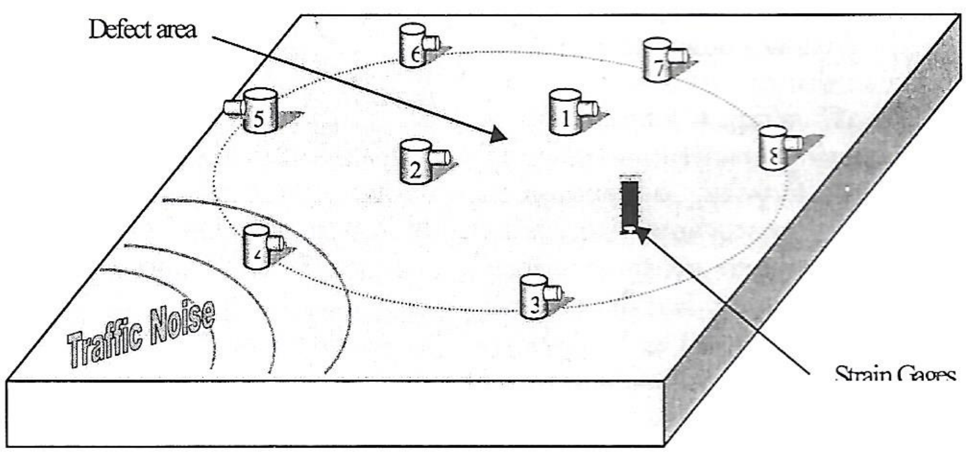

Figure 2. Typical experimental setup.

with the AE. Up to 8 data sensors can be used with as many as 8 guard sensors. As many as 4 strain gauges can be connected to the LAM through the high speed parametric input. Additional low speed parametric inputs (up to 6) can be used if it is desired to sample other sensors such as wind speed indicators, thermocouples, traffic counters, and other low speed devices.

Remote operation and data retrieval

The most often used configuration is to monitor several defects on a single bridge using multiple LAM's. This is accomplished by connecting the LAM's to each other using an RS-485 Multi-drop, twisted-pair communications line and remote data retrieval using an external modem and a remote PC.

With the setup shown (see Figure 3) , the bridge engineer can dial up the set of LAM's and download data. Results of the remote data analysis can be used to decide if the defect being monitored requires additional attention.

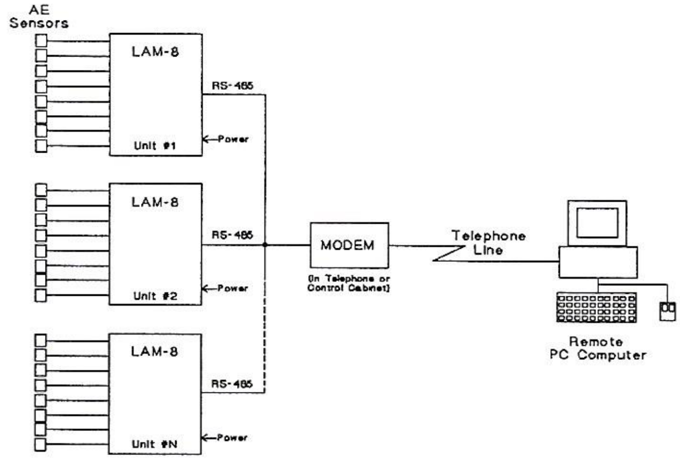

Figure 3. Multiple LAM's and remote communication.

Data processing

Feature based AE and RF waveforms can be recorded and compared to other signals recorded through the parametric input. This allows data to be filtered based on the applied loads, AE signal characteristics and source location. Thorough data analysis can provide information about defect growth rate and direction.

FIELD EXPERIENCE

The first field experience on an operating bridge was the George P. Coleman bridge in Yorktown, Virginia (see Figure 4), October, 1996. Sensors were mounted on the south, steel pivot box girder and the remote operating features of the system were tested. RF wireless modems worked fine but were limited due to the distance at which the receiver must be located. Cellular modems were tested with limited success due to problems with the commercial remote control software purchased for the system. Improvements have been made in this area as we generated our own software. A complete investigation of the north and south pivot

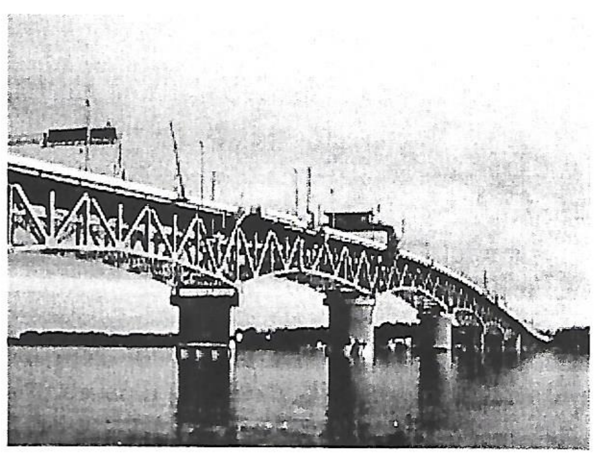

Figure 4. Coleman bridge tested in 1996.

box girder was performed and reported by the Virginia Transportation Research Council [4].

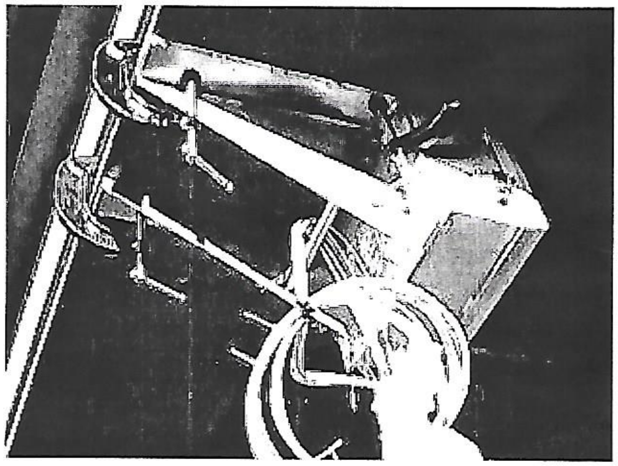

Figure 5. LAM mounted on bridge with crack in stiffener.

The second experience took place in November, 1998 on the Route 1 bridge south of Washington, D.C. (see Figure 5). Sensors were mounted near a weld crack in a longitudinal stiffener plate. The test was designed to determine if the crack had been arrested. The results of data collection showed very little activity coming from the crack area indicating that it had been arrested. Verification of the test data was accomplished by performing pencil lead breaks before and after data collection. This test also feature the use of solar power backup for the first time.

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