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Hardware Requirements for Remote Monitoring of Fatigue Cracks in Steel Bridges Using Acoustic Emission Technology

by Dio Yoshino and A. Shakoor Uppal

Summary

For several years, Transportation Technology Center, Inc. has been using acoustic emission (AE) field monitoring on the welded steel bridge at the Facility for Accelerated Service Testing (FAST) as part of the AAR Strategic Research Initiatives. Results of the monitoring have shown that AE technology can be an effective method for determining fatigue crack activity in steel bridges.

Due to the intermittent nature of crack growth, it is necessary when using AE technology to monitor railroad traffic for several weeks to assess crack growth rates. In order to cost-effectively carry out long-term fatigue crack evaluations, a remote monitoring system was developed. The objective of the system is to allow an AE operator to leave the bridge site after the initial setup is complete and monitor the crack activity at distance from home or office, resulting in significant cost savings.

Two primary obstacles in implementing this system were remote communications and a power source. Several methods for resolving these issues were considered. The following inferences were drawn:

- Methods for remote communication were investigated. These include using wireless technology over the site's local area network (LAN), data transfer through cellular and satellite phones, two-way satellite Internet, and VoiceStream™ T-Mobile™ wireless Internet service. Of these technologies, the wireless LAN was found to be the most viable method.
- Remote monitoring of AE at the steel bridge at FAST was conducted over several months through the wireless LAN. The bridge laptop computer was controlled from an office computer using remote monitoring software, eliminating the need to visit the test site for data collection. The VoiceStream T-Mobile wireless service showed that the remote bridge could be monitored from any computer connected to the Internet, if the computer at the bridge site is located within the service coverage area.
- The preferable way to power the AE collection equipment is with a local power source such as a 110-volt landline or an existing generator. If local power is not available, a portable 1-kilowatt diesel or gasoline generator can be used. A stand-alone solar powered AE system has been developed by TTCI.



INTRODUCTION

Wireless LAN

At Transportation Technology Center (TTC), 4-miles separate the Operations building from the AE monitored bridge. The computer at the bridge site is configured for remote control by an office computer through the wireless Local Area Network (LAN).

A directional antenna is attached to a support near the trailer that houses the AE collection equipment. The antenna is positioned to point to a wireless LAN repeater tower about 1 mile away (Figure 1). Both the office computer and the AE collection computer are loaded with remote monitoring software — in this case pcAnywhere™ and Netop™ — that allows the user at the office computer to view the desktop of the remote computer and have complete control. The office computer can change software settings or reboot the remote computer when necessary. Communication between computers is performed with 802.11b wireless technology and operates at a speed of 10 megabits per second (Mbps) over the LAN. Also known as “Wi-Fi,” 802.11b is a specification for wireless local area networks (WLAN) developed by the Institute of Electrical and Electronics Engineers. This allows for the transfer of a 4-megabyte Microsoft Excel™ data file in about 10 seconds.

The refresh rate of the visual display while using pcAnywhere over the LAN is only a few milliseconds, which means working from the office computer is very similar to being at the remote computer. When communicating with 802.11b technology, a direct line of site is required between directional antennas. This is because 802.11b transmits data using microwaves, which can be blocked by trees or solid objects.

Most railroad bridges are not located near a central office, but if the bridge is within a reasonable distance, a wireless link may be possible. A directional antenna is reliable up to a distance of at least two miles with proper antenna alignment.

The system at TTC operates over a wireless LAN because the LAN was already in existence. However, a similar system

could be created with two laptop computers, two directional antennas, and remote monitoring software installed on both computers. A LAN is not necessary.

Cellular Phone

Data transfer over cellular phones has been successfully tested on previous projects at TTC. The average 2-way data transfer rate was about 5.0 kilobits per second (kbps). This was determined to be too slow for transfer of AE data files and much too slow for graphically intense remote monitoring applications. Cellular communications are performed through a network of base stations located across the country. To access the network, a cell phone must be within a few miles of a base station. Service areas are generally limited to areas located in and around major cities and highways. As with standard voice-only mobile phones, the service is sometimes unreliable even within coverage areas.

Satellite cell phones can reliably operate virtually anywhere with a direct line of site to the proper satellite, enabling their use in rural areas. The speed of satellite cell phones is similar to that of regular cell phones at 5.0 kbps. This technology has been successfully tested on other projects at TTC, but was not tested for the AE application due to the low data transfer rate. The large initial equipment costs and high per-minute charges also make satellite phones prohibitively expensive.

VoiceStream™ T-Mobile™ Wireless

The majority of railroad bridges are not located near an AE operator’s central office building. Data transfer through the VoiceStream wireless network may be a solution. Connection speeds can currently reach about 100 kbps for uploading and downloading data, allowing for reasonable file transfer times and remote monitoring capability. The service is similar to cellular service in its use of grounded base stations located in densely populated areas. For rail lines close to major highway systems, this technology may be a viable option for many bridges. The VoiceStream T-Mobile Internet system uses GPRS (General Packet Radio Service) for data transmission. The only required hardware is a VoiceStream wireless PCMCIA card.

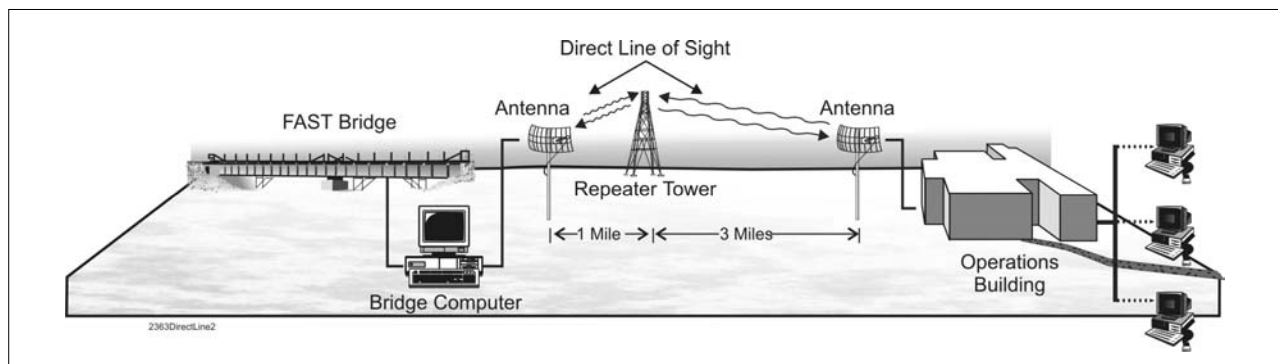


Figure 1. Communication with Bridge Computer over TTC Wireless LAN

To test the service, a 4-MB Microsoft Excel file was transferred over the network. The transfer time was about 3 minutes. This amount of bandwidth usage is probably undesirable from a cost standpoint. However, future versions of the AESmart software could be programmed to produce text versions of Microsoft Excel data files, which would be a fraction of the previous size and much more feasible for Internet transfer.

Remote software was also tested over the VoiceStream network. On observation, the screen refresh rate was about 1 second while viewing the remote desktop. This is acceptable for real-time remote monitoring. The per-minute bandwidth usage with remote software is thought to be similar to the bandwidth usage during file transfer. The software may be set to a lower screen resolution to reduce bandwidth.

The primary advantage of VoiceStream service is that the computer at the bridge site can be accessed from any computer equipped with remote software connected to the Internet. The main disadvantage of this service is that the bridge computer must be within a few miles of a base station and a strong signal must be achieved for the service to work.

Satellite Internet

For truly remote bridge sites, the only option where remote data collection is desired through a two-way satellite connection. Satellite dishes require only a source of power and a view of the southern skies in order to transmit data. The download speeds can approach 1 mega bits per second (Mbps), but the upload speeds are currently only about 30 kbps. File transfers and pcAnywhere rely on upload speeds for smooth operation. There will be some latency (delay) in the connection due to the great distance the signals must travel (Figure 2). Future versions of satellite Internet systems will use satellites with lower earth orbits to improve latency. Systems with greatly increased upload speeds are also planned. For any two-way satellite system that is capable of uploading (sending) data to the satellite, extreme precision is required when aligning the dish. For this reason, the Federal Communication Commission requires professional installation for two-way systems.

Satellite broadband service offers an “always on” Internet connection and a monthly fee is billed.

Railroad Communications

Typical railway communications between train crews and dispatchers take place on the 160 MHz railroad VHF band. Other bands available to the railroad are 220 MHz, 450 MHz, and 900 MHz. The 220 MHz channels are used for remote control locomotive technologies while the 450 MHz channels are available for cross band and control link applications. Communications paths vary from 15 to 25 miles depending on the antenna, power output, and terrain conditions. The practice of frequency re-use every 70 to 80 miles is promoted nationwide to maximize spectrum efficiency among the shortage of frequencies. Field communications find their way back to dispatch centers through a myriad of communications links including radio frequencies, microwave, phone networks, and fiber optics.

The typical data throughput for current 160 MHz equipment is on the order of 4.8 kbps, which is sufficient to transfer small text files and allow software changes with remote software.

Power Sources

Some railroad bridge sites have an existing power line or diesel generator to support AE equipment. At most other locations, local power is unavailable. For these locations, a portable power source would be required. The estimated power requirements of the AE system are:

Mandatory Equipment	
Laptop computer:	20 watts
AE equipment:	30 watts
Signal conditioner:	1 watt
Optional Equipment	
Communications equipment:	1 watt

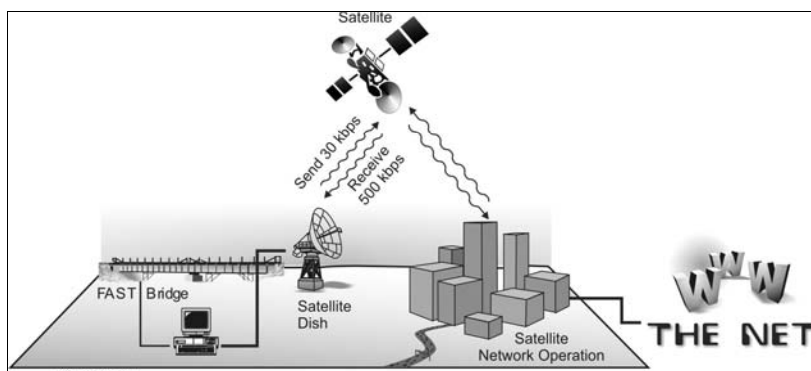


Figure 2. Satellite Communication

Based on the above data, any portable power source would need to provide at least 51 watts of continuous power. Several options for power were considered. These include gasoline/diesel generators, solar panels, and hydrogen fuel cell generators. Generators are a cost-effective and proven source for portable power, and are therefore the primary choice to power remote AE systems. A 1-kilowatt generator should be sufficient to power the basic AE collection system and any additional equipment. The downside to generators is that they are noisy and have emissions. Also, AE operators must refill the fuel tank every few hours, forcing their presence at the test site. To allow the operators to leave the test site while still collecting data, alternate portable energy methods were investigated.

The AE monitoring system at TTC currently runs on solar power. An array of eight solar panels covers the top of the AE trailer, supplying about 360 watts of DC electricity when the sun is shining. This power flows into a voltage regulator that then charges a pair of batteries. All necessary components of the system were modified to operate with DC power directly from the batteries. With an average system power consumption of 50 watts, and accounting for days with little sunlight, the 360 watts provided by the solar panels is more than sufficient.

To reduce noise and emissions from standard generators, hydrogen fuel cell generators were also investigated. Their high cost and need for frequent recharging currently make them unfeasible for a remote monitoring application.

RESULTS

Remote monitoring of railroad bridges can be a viable crack-growth inspection option for bridges with access to existing power and wireless services. Bridges located near large cities and major highway routes are likely to fit in this category. Wireless data transfer could be conducted with 802.11b wireless technology or through the VoiceStream service, or any similar technologies. For remote bridges in rural areas, the cost of monitoring is higher. These bridges require a generator for power or the creation of a solar-powered system. For most rural bridges, two-way satellite Internet is the only option for remote communication. Table 1 compares power sources and Table 2 compares advantages and disadvantages of various remote monitoring technologies.

Table 1. Power Sources

Technology	Advantages	Disadvantages
Local Power Line	Ideal	High installation cost if not already available
Generator	Inexpensive, easily obtained	Noisy, operator must remain at test site
Solar Power	Clean, no long-term costs, operator can leave test site for long durations	System setup requires some expertise; panels are prone to vandalism or theft; adequate sunshine necessary

Table 2. *Remote Monitoring Technologies

Technology	Advantages	Disadvantages
Wireless LAN	Very high speed, very reliable, inexpensive	Operators office must be within a few miles of bridge
Cell Phone	Familiar technology	Low speed, moderate reliability, bridge must be near a repeater tower
Satellite	Bridge can be located anywhere	Expensive, moderate speed
Railroad Communications	Accessible to all railroad bridges	Low bandwidth, untested

*An additional consideration for any revenue service test is protection from vandalism.

FUTURE WORK

Rapid advancements in data transfer over wireless technologies, including the upcoming 3 G network, should allow for faster and more effective systems for remote monitoring. A revenue service test on a railroad bridge has been underway on CN.

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