ADVANCES IN ACOUSTIC MONITORING

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1. INTRODUCTION

Advances in the technology of digital sound level analyzers have made automated acoustical monitoring an even more powerful tool for assessing and investigating environmental noise. In particular, advances in digital memory allow vast amounts of high resolution data to be gathered, which can be very useful in the context of temporal and spectral analysis. Perhaps the most significant aspect of increased memory capacity in acoustical monitoring equipment is the option to collect continuous audio recordings, remotely, for days to weeks at a time. Not only do audio recordings allow us to "listen in" on monitoring periods of interest during post analysis, they turn acoustic monitoring equipment into silent sentinels that never need to eat or sleep. In some cases, practitioners no longer need to remain as continuous observers in the field (both figuratively and literally); coupled with advances in deployable solar power systems and cellular modems, acoustical data and audio recordings can be collected remotely for weeks, months or even longer without the need for a technician or acoustician to be present. However, the old engineering adage of "too much data can be a bad thing" is an important consideration when it comes to advanced acoustic monitoring. Not only can gathering vast quantities of data present a challenge to analyze and derive meaningful insight from, it can also become a formidable challenge to maintain and protect the data itself.

This paper explores the evolving uses of acoustic monitoring, as well as advances in monitoring equipment and new capabilities afforded therefrom. Also discussed are some of the challenges related to conducting long term outdoor acoustic monitoring with regard to deployment and maintenance logistics, concurrent data collection (e.g. meteorological and/or operating parameters of a facility of or specific equipment of interest) and post analysis, including lessons learned from field experience.

2. EVOLVING USES

Monitoring of environmental noise is most certainly not a new phenomenon – we have been monitoring noise from airports, large industries, major transportation thoroughfares and the like for decades. However, such monitoring systems have, in past, been typically permanent stations equipped with continuous grid power and hard-wired data transfer systems, all wrapped up in bulky housings to protect the devices within from the elements. Such systems are quite expensive, and offer very little operational flexibility, particularly with regard to mobility.

The latest in acoustic monitoring technology no longer consists of a permanent fixture; smaller, more advanced and robust systems can be deployed nearly anywhere and for any length of time. Transfer of measurement data, via either a hard internet connection or cellular modem, allows for virtually real-time data acquisition. Behind us are the days where one must wait until the end of a deployment period to begin analyzing the recorded data or, in some cases, find out that some component of the deployed system had suffered a failure during the deployment period. Moreover, autonomous monitoring systems require significantly less resources to maintain; one needn't visit the equipment on a regular basis to refresh batteries or offload saved data to relieve what, in past, has been very limited storage capacity. Such advancements offer significant efficiencies for long-term monitor deployment, such as that routinely undertaken for assessment of wind turbine noise. Such monitoring campaigns can span many months in order to capture sound levels both with and without the wind turbines operating, under a prescribed variety of meteorological conditions.

Noise complaint investigations, particularly when the sound(s) of concern are intermittent, are dramatically more sophisticated when monitoring equipment can be deployed at or moved amongst multiple locations within a given community for any length of time. Audio recordings, either continuous or for short durations triggered by a measured sound level exceeding a specified threshold, allows investigators to listen to a given period or event, and focus on the sound(s) of concern, separate from other background sound. An acoustical specialist needn't be present in the field for long periods in order to "catch" the sound(s) of concern.

Construction vibration monitoring is becoming a more common occurrence in highly urbanized areas where there is increased potential for damage to structures adjacent to a demolition or construction site. Continuous vibration monitors equipped with real-time communication capability can issue a report the moment that vibration levels exceed a threshold of concern; construction activities can then be halted and the approach adjusted to ensure protection of surrounding structures.

The following sections discuss the primary components of an acoustic monitoring package, along with the associated strengths and weaknesses of each.

3. PRIMARY COMPONENTS

3.1 Measurement Device

The central component of any monitoring system is the measurement device itself, be it for sound, vibration or both. When equipped with a means of remote communication (discussed further in a following subsection), the latest measurement devices can be configured and re-configured remotely, which can reduce occurrences of costly configuration errors (that may not be discovered until the end of a deployment) and offers greater adaptability. As noted above, some measurement devices can be configured to trigger recordings of a pre-determined dataset when a sound or vibration threshold is exceeded, which reduces the total amount of data stored in local memory, thereby extending the deployment period in cases where the data is not being downloaded remotely. Another significant feature

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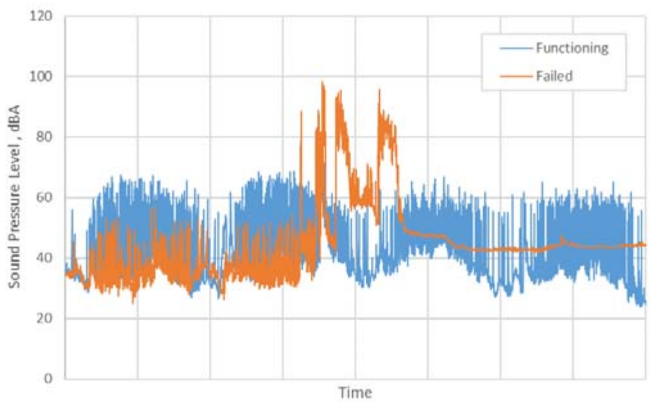
of today's most advanced monitoring devices is the ability to self-test the integrity of the microphone on a regular basis to ensure that the device is functioning correctly. Such a feature can help to avoid costly losses of key datasets and/or monitoring time. Figure 1 provides an example of an in situ failure of a deployed sound level monitor.

Fig. 1. Example of sound levels recorded by two nearby monitors where one device failed in situ, as evidenced by the "flat lining" of one dataset.



3.2 Power

Advances in portable solar power systems have made it possible to deploy acoustic monitors for extended periods in very remote areas (where grid power is not available), without the need for regular maintenance visits by a technician in order to refresh batteries. This represents a significant boost in efficiency of time and resources for a given acoustic monitoring campaign. In the event of a temporary power interruption (resulting from a solar power system that becomes temporarily covered by snow, for example), many advanced measurement devices will simply restart when the power supply becomes available again, and resume monitoring immediately.

3.3 Memory

The built-in (or replaceable) memory capacity of the latest acoustical monitoring devices has increased significantly in recent years, with capacities of 32 GB or more being common. Such significant memory capacity means that equally significant amounts of data can be collected and stored, including triggered audio recordings, and limited periods of continuous audio. Lower quality audio recordings (which consume far less memory) can be quite sufficient for listening to identify sounds during periods of interest; audio recordings of sufficient quality to be post-processed can consume significant amounts of memory over relatively short periods.

3.4 Data Transfer

Whether via a hard-wired or Wi-Fi connection to the internet, or by cellular modem, being able to transfer data at will from a remotely deployed acoustic monitoring system allows data to be analyzed sooner (rather than having to wait until a technician retrieves the data from the equipment in the field), and facilitates ensuring that the monitor is still functioning as expected. If a monitor is deployed for a period of several weeks and experiences a hardware failure early in the deployment, being able to detect and resolve such an issue early is a significant strength of recent, downloadable monitoring systems (rather than finding out upon retrieving the equipment after a long-term deployment that some component failed two days into the campaign). With a hard-wired connection to the internet, data can be downloaded from monitoring equipment essentially in real-time.

4. LIMITATIONS

Although significant advances have been made in the complexity and flexibility of acoustic monitoring equipment, there remain several notable limitations with regard to power, memory and data transfer. With regard to power, fully autonomous solar charging systems must be deployed in areas with sufficient solar exposure, which can be limited due to foliage, snowfall, or even limited sunlight due to prolonged periods of heavy cloud cover or short days in extreme northern/southern locales. In addition, the size of solar panels and weight of accompanying batteries can be a challenge to deploy and retrieve in very remote areas. Finally, large solar panels can make the monitoring equipment quite visible, increasing the risk of being vandalized or stolen.

Despite the obvious benefits afforded by cellular modems, they consume significant amounts of power (relative to the power needs of most measurement devices), and can thus strain a system that relies on batteries alone, or limited solar systems. While this can be mitigated by scheduling "offline" time to conserve energy (the modem automatically goes online at scheduled intervals to report equipment integrity, upload data, etc.), this can nevertheless be a significant design consideration when developing a fully portable system capable of long-term deployment. In addition, cellular modems introduce a potential failure point in an acoustic monitoring system that is secondary to the measurement device(s) themselves, and can sometimes consume valuable troubleshooting time. Finally, depending on the data transfer rate of a given data transfer media, the rate at which data is collected may exceed the transfer speed, such that the internal memory will reach capacity at some point, limiting the deployment life of the system.

5. LESSONS FROM FIELD EXPERIENCE

Indeed, too much data can be a bad thing. A noise complaint investigation involving deployment of six acoustical monitors collecting sound levels and continuous audio recordings for a period of approximately three months generates a tremendous amount of data, both in terms of digital memory, and for post-processing. Synchronized with concurrent meteorological data and varying operating conditions of an industrial site the size of a small town, deriving meaningful conclusions from such a volume of information can be a significant challenge. Moreover, the maintenance and backup of several terabytes of data for just a single project can be a daunting task.

The application of advanced acoustical monitoring must therefore be carefully thought out in order to ensure that an appropriate amount of data is collected in the context of a given challenge. When advanced monitoring assets are readily available and easily configured to collect massive sums of data, it can be all too easy to bring to bear far more resources than are necessary in order to complete a given task. In that regard, all of the efficiencies afforded by advances in monitoring technology can be offset by the time spent administering and deriving meaning out of the tremendous amount of data that can be readily collected.