Cost-Effective Wireless System for Large-Scale Noise Monitoring

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This article presents a cost-effective sound monitoring system that uses wireless technology for publishing data. The system posts sound levels on a website at a preset time interval and eliminates the cost of regular site visits to confirm the operating status of the monitors and to download data. In addition to regular data posting, the system instantly sends out messages to computers and cell phones when the preset sound criteria are exceeded. This allows the system to be used for construction noise monitoring. To help the construction team to identify the noise sources of an exceedance event, it also posts an audio recording of the events. The system has been monitoring construction noise at the Caldecott Tunnel Fourth Bore in near Oakland, CA, since May 2010. This article describes the performance criteria of the system, design considerations, main components, and application executions.

A fourth bore is being added to Caldecott Tunnel on Highway 24 near Oakland, CA, to provide two additional lanes to relieve the daily traffic bottleneck. When completed in 2013, the four-year, $430-million project will provide a new 3,389-foot-long tunnel with two 12-foot lanes, shoulders and emergency walkways. In response to noise concerns of the residents around the construction site, Caltrans (California Department of Transportation) has agreed to monitor evening and nighttime noise in residential neighborhoods near the tunnel's west portal. Figure 1 shows the six community sound monitoring stations and the vicinity map of the construction site.

The project has distinctive requirements for sound monitoring, such as continuous sound monitoring, instant alarm of any exceedance, and audio recording of all exceedance events. The construction team is required to stop construction within 20 minutes of any noise exceedance unless it is verified that the exceedance is not caused by construction activities. To fulfill these distinctive requirements, we had to develop a new wireless sound monitoring system using Scantek instrumentation. Figure 2 shows photos of two monitoring stations.

Figure 1. Sound monitoring stations and vicinity map of Caldecott Tunnel near Oakland, California. Sound monitoring stations marked as PS1 through PS6. (©2010 Google Imagery; ©2010 DigitalGlobe, USDA Farm Service Agency, GeoEye, U.S. Geological Survey, map data)

Figure 2. PSW wireless sound monitoring stations.

Performance Requirements

The following are some of the performance requirements for the monitoring system.

- Sound Level Meter – The project specifies Type II sound level meters that meet ANSI S1.4:83 (A1:85) and ANSI S1.43:97 standards.
- Sound Monitoring – The project requires continuous sound monitoring at six community stations plus four construction stations. It requires public posting of hourly L_{eq} and L_{max}, in dBA from 7 p.m. to 7 a.m. the next day.
- Noise Criteria – The project requires a two-week continuous noise monitoring at each community monitoring station before the start of any construction work. Based on the monitoring results, the L_{eq} and L_{max} criteria are established for each station at each hour between 7 p.m. and 7 a.m. for weekdays and weekends.
- Instant Alarm – The project requires the construction team to stop working and apply noise control measures within 20 minutes when the sound levels exceed the criteria at any monitoring station. To meet this requirement, the construction team needs to be notified as soon as an exceedance event occurs.
- Noise Source Identification – Since the monitoring stations are located in populated areas, the exceedance events can be caused by community activities such as dogs barking, moving cars, or people talking next to the monitoring station. The construction team needs the ability to identify the noise source within 20 minutes of an exceedance event.
- Internet Connection – Some monitoring stations are located in areas where cell phone signals are so weak that we had trouble making cell phone calls. The wireless monitoring system has to function in these areas.
- Weather Factor – The system has to withstand California's strong summer sun, frequent winter rains, and high wind at the hilltop stations.
- Public Website – A public website is required to serve daily data for public viewing.
- Engineering Website – The construction team should have a private website with engineering details.
- Record Keeping – All records are to be archived for future examinations.

System Design and Components

The basic components of the system include a sound level me-

ter at each monitoring station and a PSW wireless package. The sound level meter measures sound levels, and the PSW wireless package compares the levels with the criteria and posts them on the websites. When an exceedance event happens, the wireless package sends out alarms and posts the event audio recording. The system operates automatically.

Sound Level Meter. The system is designed to work with a CESVA SC-160, a Type II sound level meter meeting ANSI standards. For projects that accept IEC standards, we adapted the Rion NL-21 to the system. It is a Class 2 sound level meter meeting IEC 61672-1: 2002 Class 2 and JIS C 1509-1 Class 2 standards. Information on CESVA 160 and Rion NL-21 can be found on Scantek's website.[1]

Weather Enclosure and Microphone Windscreen. Each station is equipped with a weather enclosure and an all-weather WS-03 windscreen for the microphone. The WS-03 windscreen provides a 28 dBA or 19 dBC wind noise reduction. At the time this article was written, the weather enclosure and microphone windscreen has protected the system through the summer, when temperatures reached a few degrees above 100˚ F and through the majority of a stormy winter.

Public Websites. Two websites, a public site and an engineering site, have been established. The public website is hosted by the Caldecott Project[2] (see Figure 3). It serves the information required by the project specification, including a project vicinity map, daily nighttime L_{eq} and L_{max} at each station, and archived sound levels and exceedance events with identified noise sources. The system posts the data automatically as they are received.

Engineering Website. The engineering website, which is password protected, serves more detailed information for the project team. It includes a project site map, hourly L_{eq} and L_{max} at each station throughout the day, exceedance events along with its audio recording and sound source identification, an archive of data and audio recordings, and a log sheet revealing the operating condition of each station. In case of any station failure, the log sheet gives diagnostic information.

Hourly Data Posting. On the engineering website, at the end of each hour, hourly L_{eq} and L_{max} at each station are posted. Figure 4 shows the hourly sound levels of a demonstration system[3] that posts L_{eq}, L_{max}, L_{10}, and L_{90}. Any missing data at a station, if not recovered on its own, may indicate a problem at the station. Before implementing self-recovery logic (explained below), we experienced numerous Internet connection interruptions. With the self-recovery program, the most common failures we have encountered are power outages that last longer than a few hours. We had power outages after several storms, and local construction work also interrupted the power to a few stations.

Instant Alarm. When the noise exceeds the L_{eq} and L_{max} criteria, the wireless system sends out a text message or e-mail alarm within 4 seconds to pre-assigned cell phone numbers and email addresses. The message includes the station number and alarm date and time. At the same time, the wireless system posts station number and starting date and time of the event on the engineering website. At the end of the exceedance event, it posts the stopping time and the maximum sound levels of the event.

Table 1. Nighttime noise source identification form, November xx, 2010.

Location	Date	Start Time	End Time	Exceedance, dBA	Description
9	2010/11/xx	19:32:41	19:32:42	71.00	Airplane
9	2010/11/xx	19:32:43	19:32:51	72.70	Airplane
6	2010/11/xx	19:54:34	19:54:36	80.40	Horn
6	2010/11/xx	22:44:58	22:45:00	82.00	Car
1	2010/11/xx	23:07:38	23:07:44	83.80	People/Dog
1	2010/11/xx	23:08:35	23:08:41	80.50	People/dog
2	2010/11/xx	01:05:50	01:05:52	76.20	Motorcycle
3	2010/11/xx	03:22:36	03:22:38	76.00	Truck
9	2010/11/xx	04:10:31	04:10:32	69.50	Car
2	2010/11/xx	04:26:27	04:26:30	79.90	Truck
8	2010/11/xx	04:37:21	04:37:32	72.30	Car
3	2010/11/xx	06:06:44	06:06:45	83.40	Truck
8	2010/11/xx	06:13:15	06:13:16	79.00	Truck
8	2010/11/xx	06:13:21	06:13:22	81.00	Truck
8	2010/11/xx	06:13:24	06:13:25	78.80	Truck
8	2010/11/xx	06:13:26	06:13:39	88.10	Truck
8	2010/11/xx	06:13:42	06:13:49	89.70	Truck
6	2010/11/xx	06:15:49	06:16:00	82.20	Car
1	2010/11/xx	06:17:42	06:17:43	81.60	Air brakes

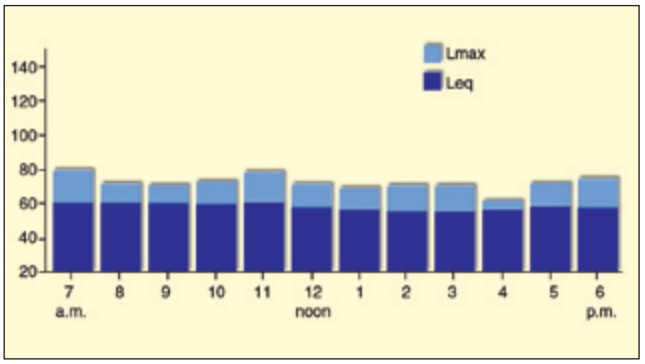

Figure 3. Hourly nighttime noise data as shown on Caldecott Tunnel project website. Sound levels at Station 1 is close to west end of existing tunnel on Highway 24 and attached to light pole at entrance to gated community. Equivalent sound levels dominated by freeway traffic noise, and maximum sound levels dominated by vehicles through gate and sometimes people and dogs.

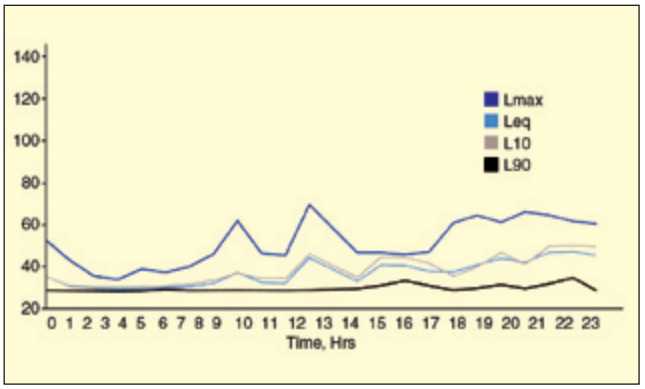

Figure 4. Hourly sound levels of demonstration system; station located inside quiet residential house, where people periodically talk near the monitoring station.

Audio Recording. Each station has continuous audio recording from the sound level meter. When the noise exceeds a criterion, the audio recording from one minute before the exceedance to one minute after the exceedance, up to five minutes, is posted on the website. The construction team listens to the recording on the website at a computer or using a smart phone to identify the noise source and fill in a form with the noise sources. Table 1 shows a noise source entry form. The non-event audio recording is kept for 48 hours then erased automatically.

In the table, all events are L_{max} exceedance events. Since the L_{max} criteria are specified as the average of ambient L_{max} levels before the construction work, false alarms caused by local cars, trucks, dogs and humans are quite common at the community monitoring stations. It is also common to have an alarm caused by a 0.1 dB exceedance for 1 second. At the current time, most alarms at west portal community stations are false alarms, because the main construction work is at the east portal of the tunnel.

Archived Data. The hourly sound levels and exceedance list, including sound source and audio recording, are archived on the engineering website. Archived data are searchable by station and time.

Wireless Data Transmission. The wireless system uses Verizon Wireless (although it can also work with WiFi or other cellular providers). It is equipped with an antenna at each station to increase signal strength. It is also equipped with a self-recovery program. When the Verizon signal is too weak or interrupted for any reason, the sound level meter continues to collect data and store the data. When the signal is strong enough, the system recovers itself and

sends out the stored data. Without the self-recovery package, the system would stop periodically. With the self-recovery program, the system runs for months without missing any data.

Power Supply. The system can be powered by grid power, battery, solar panel or a combination of the three. Due to the nature of the project, all monitoring stations are either in residential areas or on the construction site. Since all monitoring stations are attached to light poles, we decided to use the power at the light poles. Each station also has backup power that lasts a few hours.

System Summary

The PSW wireless sound monitoring system provides a cost-effective way for large-scale environmental sound monitoring. Since its operation at Caldecott Tunnel Fourth Bore in May 2010, Caltrans, the construction team, and the nearby residents are all happy with its performance. The wireless and automatic operation saves labor costs for the construction team. The archived sound levels and event audio recordings allow future examination to resolve disputes. The public website allows the residents to review noise data and exceedance events along with its noise sources. The system provides a new tool for noise compliant management.

The PSW wireless sound monitoring system[4] equipped with instant alarm and event audio recording is ideal for construction noise monitoring and recreational activity noise monitoring, such as concerts and motor sport races. It is also good for traffic noise monitoring at highways, airports, or ports, and industrial noise monitoring, such as mines, quarries, chemical plants, power stations, and wind farms.

References

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