Lost & found

Philip Shaw, SureWave Technology, UK, presents the latest developments and tests to an innovative trapped miner detection and location system.

There is an urgent, ongoing need for all mines to establish access to equipment that can detect and locate trapped miners in the event of any incident or accident.

The Sago mine disaster was a coal mine explosion in January 2006 in West Virginia, US. The explosion and subsequent collapse of the mine killed 12 of the 29 workers underground at the time. One trapped miner survived and was able to detail his experience to an investigative report by the US Department of Labor's Mine Safety and Health Administration (MSHA).

In an extract from the MSHA report on the accident, the one trapped miner who narrowly survived reported the events of the last hours of his colleagues and "indicated the crew thought they would be rescued" and that the trapped miners expected "rescuers would bring the machine that locates people to the mine" and "the crew thought that they would hear shots on the surface, rescuers would drill a hole in the right spot, and they would be taken out and discussed how long it would take". The trapped men took it in turns to bang on a roof bolt with a sledgehammer, but "as time passed it did not look good. They were waiting for the

borehole but felt that the rescuers must not have had the right equipment."

Case studies

SureWave Technology, a UK-based microseismic technology company, has developed a trapped miner detection system, the TMS2, that has been field tested at three minesites in the US Appalachian mining region. The first tests were conducted in February 2011 at Federal #2 mine in West Virginia; the second near Wheeling, West Virginia, in June 2012; and the third at Black Mountain, Kentucky, in November 2012.[1]

Poor weather and nearby surface activity have traditionally prevented seismic systems from being deployed or working effectively. However, several days of the test phases were conducted under these adverse conditions and the TMS2 system was completely unaffected. This represents great progress for seismic detection systems by expanding the range of conditions under which they can be used.

Figure 1. The SureWave system is compact and portable.

Figure 2. Deployment of portable sensors. Image courtesy of the University of West Virginia Mining Department.

Figure 3. The sensors can be daisy chained to assist deployment.

Second field test: Wheeling, West Virginia

The second set of tests near Wheeling, West Virginia, was conducted side-by-side with the MSHA system in June 2012. This mine is a 1040 ft (317 m) deep underground coal mine, and was fully operational during the tests.

The MSHA system consisted of two trucks – one containing the electronics, the other housing a generator to supply power to the system. The basic layout of the MSHA system was seven sets of seven sensors placed over as wide an area as possible, to cover the surface area of approximately the positions used underground for the simulated trapped miner tests. Each of the sensor groups had to have a line-of-sight radio link back to the electronics in the truck in order for it to work.[2]

The SureWave system consisted of two small Peli cases – one housing the main central processing unit (CPU) system containing all the electronics, the other a battery pack for power. An external car battery was also used. The complete system has been designed to be totally portable and capable of being deployed by a single person in less than an hour (Figure 1). The sensors were deployed around the site as shown in Figure 2.

As can be seen in Figure 2, the site used was in close proximity to high voltage power feeds into the mine, air feed fans and a compressor station. These generated significant seismic noise. The MSHA commented in particular that the site was extremely noisy in seismic terms. However, this noise does not affect the SureWave TMS2 system, due to its proprietary IP that "sees through" the noise and enables the detection of trapped miner signals that hitherto has not been possible. This is the major advancement in this technology, now enabling practical, portable systems to be deployed to save lives. Further, the extreme sensitivity and dynamic range allows the detection of signals thousands or even millions of times below the surrounding noise to now be detected and identified. Previously, systems have always required the desired signals to be greater than the background noise. This essential ability has garnered praise for the company as "by far the out and out leaders in this technology".

The tests were conducted over a two hour period in which "trapped" miners would pound the tunnel to simulate a miner in distress trying to attract attention. The exact times and frequency of these signals were not revealed to SureWave or MSHA. The objective was to determine if these signals could be detected. Some of these test poundings were single strikes every minute or so. Both detection systems would ideally be listening for multiple strikes at intervals of around 1 sec, in order to present the user with 100% confidence that it is in fact a miner being detected as opposed to any other seismic event. The SureWave system automatically detects miners pounding and discards all other activity. However, the system user always feels more comfortable when they can see a regular strike pattern. Despite this, SureWave was – albeit with some hesitance due to the single strike pattern – able to give the times of all the events that matched the actual times of these events, revealed some days later. The MSHA system could not distinguish signals or times with any degree of certainty due to the high background noise.

The signals were generated by the miner striking the roof, roof bolt or floor of the mine with either a timber crib block or a sledgehammer. In all the tests, the crib block striking the roof or roof bolt performed the best, with around 30% reduction in signal clarity when the sledgehammer was used.

The SureWave sensors can be either single axis vertical sensors, capable of being cabled in a row or "daisy chained" (Figure 3), or tri-axis sensors measuring in three orthogonal axes – vertical, longitude and transverse (Figure 4).

It has already been determined that the sensors need to be mounted in good contact with solid material. This

Figure 4. Triaxial sensor.

Figure 5. The sensor must be placed on solid earth.

Figure 6. As an alternative to a hole, supplied spikes can be used.

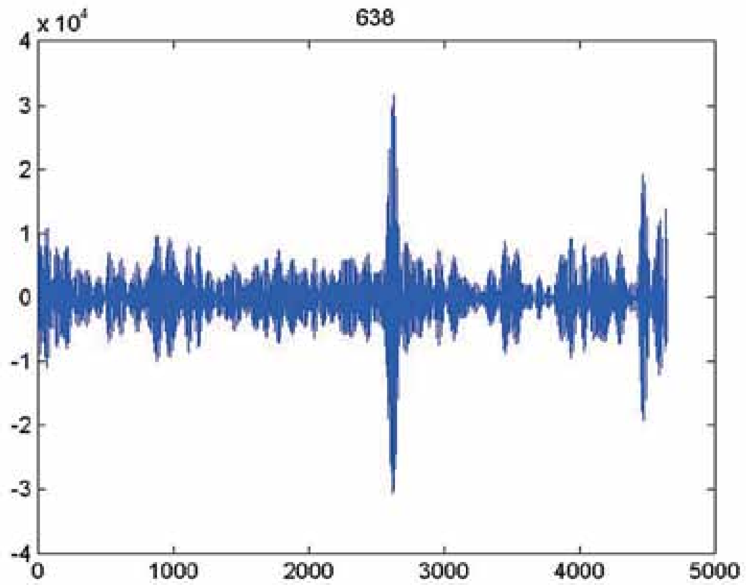

Figure 7. Example of the real-time display of a single miners strike.

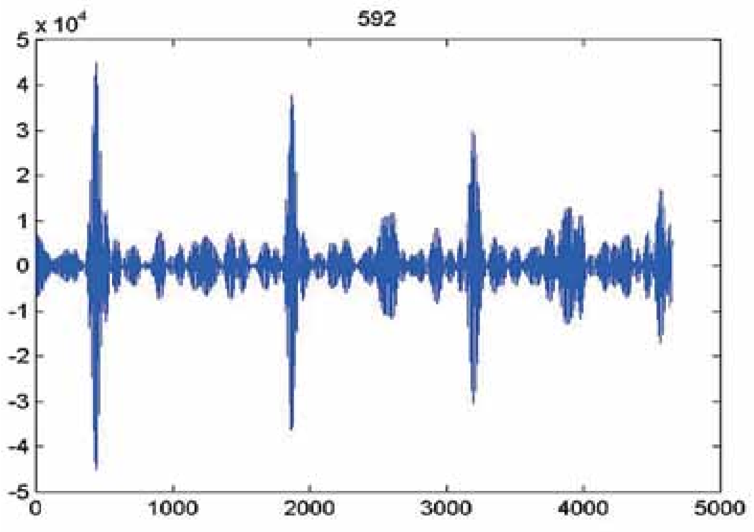

Figure 8. Example of multiple miner strikes displayed.

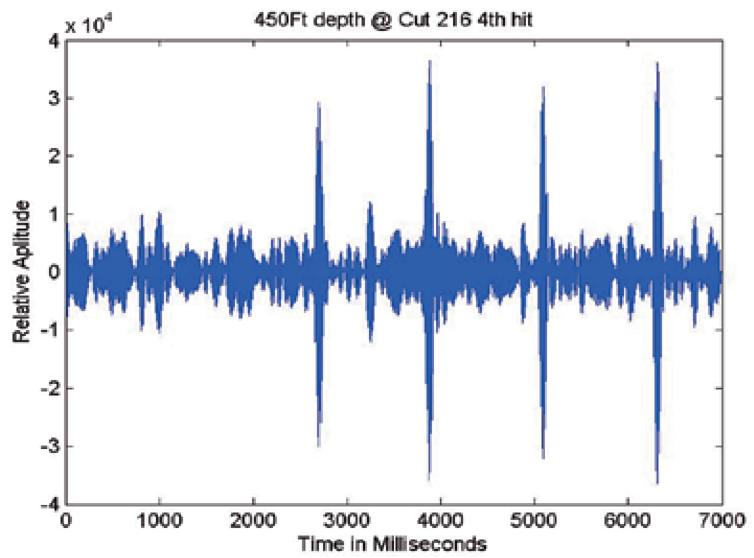

Figure 9. Detected miners at 450 ft depth.

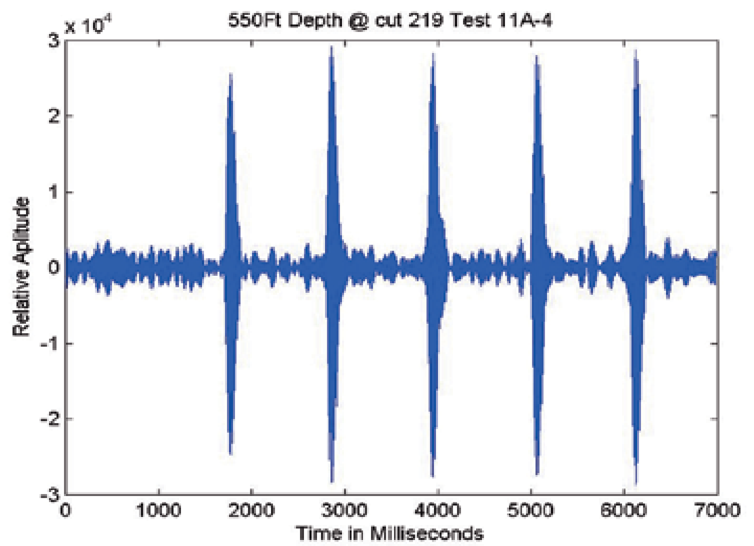

Figure 10. Detected miners at 550 ft depth.

can be achieved using an auger to produce a suitable hole (Figure 5) or by using supplied "spikes" upon which to mount the sensors (Figure 6).

An example of the real-time display of events shown on the SureWave system for a single strike is shown in Figure 7, while an example with multiple strikes is shown in Figure 8.

To further test the limits of the SureWave system, local noise was introduced with a jackhammer on a steel bar. It was determined that SureWave could distinguish signals with noise injected even as close as 100 ft (30 m) from the sensors with no detrimental effect to the systems' capability to detect the miners striking.

Third field test: Black Mountain, Kentucky

The third set of tests was conducted at Black Mountain, Kentucky, in November 2012. These tests were to establish the maximum depth of detection and to test the deployment in typical real world conditions above coal seams in rugged terrain. While the coal seam was predominantly level, differing heights of overburden could be achieved by moving the sensors up the mountain side. This technique gave working depths of 450 – 1800 ft (140 – 550 m).

The same SureWave technology system (TMS2) was deployed as in previous tests, with the very latest techniques, to present the user with a fully automatic system requiring no adjustment or user experience. The system was simply switched on and connected to the sensors deployed.

The simulated trapped miners produced a striking pattern of five hits at 1 sec intervals. These were fully detected with 100% confidence at all depths to 1500 ft (460 m). Unfortunately, at a depth of 1800 ft (550 m) the mine had a substantial amount of gob between the simulated trapped miners and the sensor position, which reduced the clarity of the detected waves. Time did not allow another site to be found at that depth for the purposes of testing the system. The miners began signalling

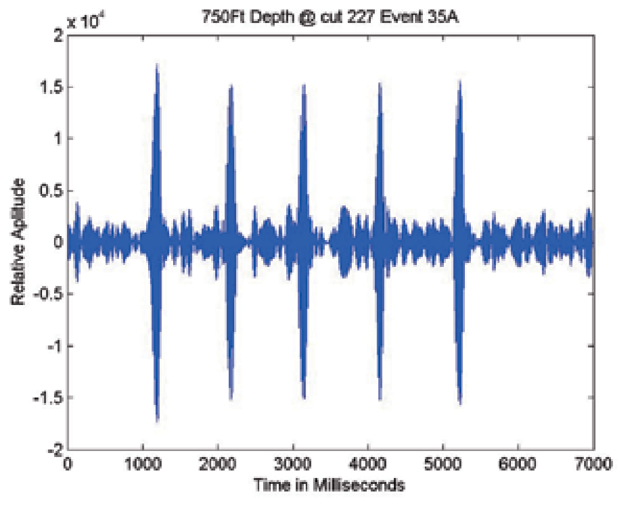

Figure 11. Detected miners at 750 ft depth.

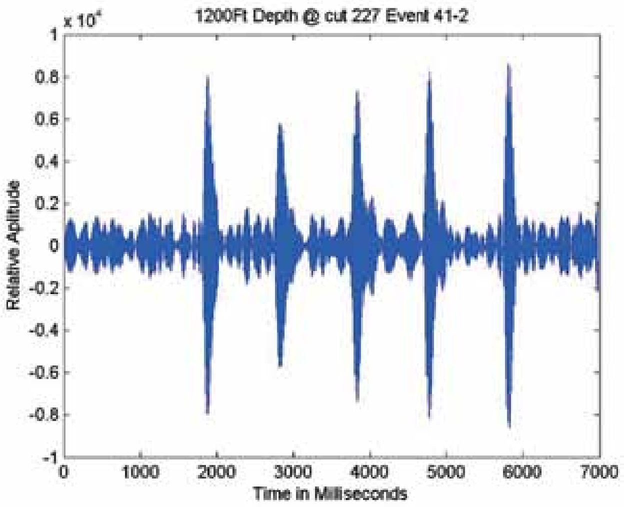

Figure 12. Detected miners at 1200 ft depth.

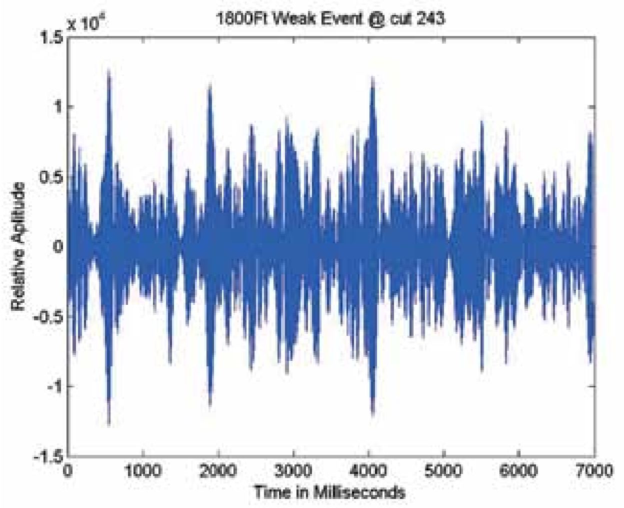

Figure 13. Signal recorded of miners at 1800 ft depth.

immediately under the sensors and then walked away to increase the horizontal distance to up to 1500 ft (460 m) with detection at 100% confidence.

The displayed signals detected at each depth are displayed in Figures 9 – 12.

At 1800 ft (550 m) depth, because of the amount of spoil the signal was not of sufficient clarity to be claimed beyond reasonable doubt to be the detection of miners in an emergency situation. The recorded example is shown in Figure 13.

Conclusion

The SureWave system has been independently observed to detect (and locate if required), trapped miners to depths of at least 1200 ft (365 m) deep at up to 1000 ft (300 m) horizontal distances at that depth. It has also been established that it is necessary for trapped miners to strike the roof or roof bolt several times (five strikes is ideal) at intervals of approximately 1 sec and to repeat this as the trapped miners' reserves of strength allows. In addition, if the circumstances permit, trapped miners should strike different parts of the roof and move around a section or cross cut so as to avoid bad sections, or areas where voids are above the immediate section and severely degrade the recovered signals. This last point proved a surprising result during the last tests at Black Mountain. During a horizontal distance test (where the miners start directly under the sensors and then walk away), striking at 200 ft (60 m) intervals, sections were struck where no recorded signal was observed, but subsequent sections (further away) produced clear results. The only plausible explanation was that there were bad roof sections (loose material or hollow sections) or voids/old workings between areas struck and the sensors on the surface that impeded the signals.

From the first tests at Federal #2 mine to those conducted at Black Mountain, the system has been perfected to remove any and all user intervention or setup and to automatically detect and discern trapped miner signals from the noise and give the user confidence by displaying the recovered signals from the miners pounding. The determination of the best pounding method (crib block on roof) and to provide a clear pattern for user comfort, gives a ready to use, off-the-shelf detection system.

This is capable of saving lives in mines in the event of incidents, such as the Sago mine disaster, where time was critical and the availability of the system in the local vicinity would have been paramount. This is state-of-the-art technology now offering the real opportunity to save miners lives trapped many hundreds of feet underground, which has never before been available. WC

References

1. The results of the first set of tests at Federal #2 mine were reported in an earlier case study. See SHAW, P., "Ground Breaking" in *World Coal* 20:11 (November 2011), pp. 37 – 42.
2. A demonstration video of this system can be viewed online: www.youtube.com/watch?v=AXBsrDSgUjM