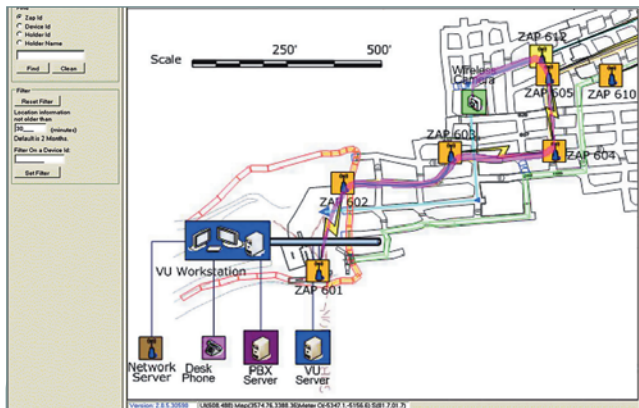


# UNDERGROUND COMMUNICATIONS & TRACKING SYSTEMS UPDATE

*Integrators and OEMs gain approval for new communications and tracking systems*

BY STEVE FISCOR, EDITOR-IN-CHIEF



Several new systems, such as the SWS Subterra VU (above), have been developed to communicate with and track miners.

Following the three mine disasters in 2006 and subsequent legislative actions, the coal mining business witnessed a rush of communications specialists that thought they had the answer as to how to communicate, track, and locate miners. Most of these systems developers realized from the onset that mining is a tough business that requires resilient equipment and they now have more respect for the dips and rolls created by different geologic formations. They also have an appreciation for the thorough certification and approval process used by the Mine Safety and Health Administration (MSHA) and state regulators.

Today, when it comes to communications and tracking systems, coal mining companies have choices—maybe more choice than they need. These systems are a direct response to the MINER Act of 2006 and the West Virginia Legislative Rule §56-4-8 for Mine Safety and Tracking and Communications Systems. West Virginia was the first state to require communications and tracking in underground coal mines to aid in the escape and rescue of miners. The state's goal is to have all West Virginia mines in compliance by the end of 2008. After defining the performance requirements for integrated communication and tracking, the Office of Miners' Health Safety and Training (OMHS&T) began the review and approval of manufacturers ([www.minesafety.org](http://www.minesafety.org)).

As of December 31, 2007, MSHA has observed the testing or demonstration of 27 communications and/or tracking systems at various mine sites. The agency met with representatives from 61 communications and tracking system companies. To date, it has had discussions with various vendors regarding 162 different proposals for development of mine communications and tracking systems. Since the beginning of 2006, the agency has issued 35 new or revised approvals for communications and tracking products. It is currently investigating 43 approval applications for communications and tracking technology.

Several companies agreed to speak with *Coal Age* about their products. All of them have communications and tracking systems that are either approved by MSHA or submitted for approval. Generally, they can be separated into two camps: leaky feeder and purely wireless.

Most of the wireless systems are based on the IEEE 802.11 (WiFi) or 802.15.4 (ZigBee) radio specification. Most operate at 2.4 gigahertz (GHz). Wireless systems use access points or nodes to create a self-forming, self-healing ad-hoc mesh network for communications. The leaky feeder system uses a cable strung throughout the mine as an antenna. Most mines are familiar with very high frequency (VHF) systems that operate on the yellow stranded cable. New, more future-proof ultra high frequency (UHF) systems are being developed. One of the more popular cables is Radio Frequency Systems' (RFS) Radiaflex cable. Most of the tracking systems use a radio frequency identification (RFID) tag and a set of tag readers to determine the location of a miner or a piece of equipment.

The industry has decisions to make. Affordability is always a concern and the starting price seems to be in the \$3 per linear foot range for a relatively simple leaky feeder system. West Virginia has set the current standard by allowing leaky feeder systems, but MSHA has not yet given its interpretation of certain aspects of the MINER Act, namely the term "wireless." Back-up power capacity is also a serious technical concern that impacts the viability and cost of the system. The rescue chambers have been designed to support life for at least 96 hours. One would think the communications systems should last as long as the rescue chambers' ability to support life. A longer duration, however, requires a larger battery and hence the greater difficulty to achieve intrinsic safety. These decisions and others could raise the price of coal going forward.

## Pillar Innovations Develops UHF Leaky Feeder System

Pillar Innovations partnered with Becker Electronics, which had a long-standing relationship with RFS. Its system is designed around the RFS Radiaflex leaky feeder cable. "We investigated a number of different communications systems and architecture options," said Adam Brenneman, product manager, Pillar Innovations. "We elected to use leaky feeder because of its familiarity underground and we felt it held some promise as being forward compatible." Brenneman explains that, when Pillar Innovation was developing its communication system, they set three goals: open architecture, production use, and forward compatibility.

With an open architecture, which means the system has no proprietary communications technology, Pillar Innovations knowingly ran the risk of leaving the door open for other vendors to support the system, but it gives the mine a high level of comfort knowing that their systems are based on an industry standard.

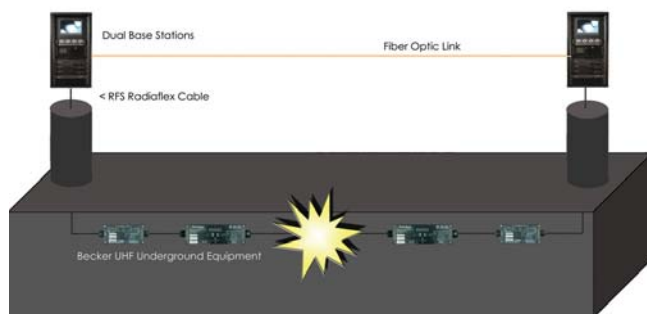
The reasoning behind having an emergency voice communications system that is also used for production purposes is that Pillar Innovations believes the mines will use and maintain a production system. "If a mine is forced to install a system simply to satisfy a safety rule, it will more likely be neglected," said Brenneman. "Similar to self-rescuer training, if it's not used day-to-day, there will be a level of unfamiliarity with the system."

Forward compatibility is important especially as fast as technology is moving today. Pillar Innovations did not want to install a system in a mine that is obsolete in five to 10 years. The forward compatibility aspect led Pillar Innovations to RFS because the company's Radiaflex cable supports the higher frequencies. "The MSHA-compliant cable supports up to 6 GHZ in a variety of different technologies. So it's what we consider future-friendly," said Suzanne Kasai, business development manager, RFS.

A lot of the leaky feeder systems were installed underground with the yellow stranded cable. That works fine for VHF communications, but it can't support higher frequencies over longer distances. "That's the reason we decided on Radiaflex," Brenneman said. "That way, we do not lock the mines into UHF technology, which is current, but may not be in the future. No peripherals [e.g. hand-held radios] exist for underground coal that run 2.4 GHZ across leaky feeder systems. However, if they become available, the backbone is there and ready."

The Radiaflex cable serves a dual role in this system. It is the power conductor (12 volts dc) and it's also the antenna. The system is supported with power every 6,000 ft, which coordinates well with the length of conveyor flights. "Not all leaky feeder systems are created equal," Kasai said. "Some of the capacitance and inductance values of the RFS cables has been what has enabled the success of the system that Pillar Innovations has designed." RadiaFlex fits well with MSHA approval regulations.

Redundancy and hardening are two of the biggest issues that Pillar Innovations has had with leaky feeder systems in general. The big question was: How could they design a system to survive a mine explosion? Brenneman explains that it mostly has to do with how the system is laid out underground in terms of power segregation. The system is engineered so that, if one component goes down, it doesn't take the whole system with it. "Nothing will withstand a roof fall, but what the system has to do is recover from that and recognize that something has happened," Brenneman said.



The Pillar Innovations leaky feeder system relies on an alternate path to the surface for redundancy.

## MSHA Approved Communications & Tracking Technologies

(January 8, 2008)

Manufacturer	Model Number	Approval #
<b>Handheld Two-Way Radios</b>		
Kenwood USA Corp.	TK-290, TK-390	23-A060002-0
Leaky Feeder Communication Systems		
Mine Radio Systems	Flexcom Comm Systems	9B-219
Varis Mine Tech.	Model IS Leaky Feeder Comm System	23-A050001
DAC	Type RFM 2000 Radio System	9B-201
EL-EQUIP, Inc.	VHF-1 Radio System	9B-196
Tunnel Radio of America	UltraComm Distributed Antenna Comm System	23-A0700050
<b>Mine Page Phones</b>		
Control Corp.	Loudmouth Page Phones	9B-71
Gai-Tronics	Model 491-204 Mine Dial Page Phone	9B-71
Gai-Tronics	Part Nos. AM7011, AM7012, AM7021, AM7022 Loudspeaking Telephones	9B-155
Pyott-Boone	Model Nos. 112 and 112P, 118 and 119 Page Phones	9B-102, 9B163
Pyott-Boone	Model 128 Mini Page Boss	9B-158
Mine Safe Electronics	Model IIA Mine Phone	9B-164
Mine Safety Appliances (MSA)	Pager III	9B-85
<b>Radio Frequency Identification (RFID) Tracking Systems</b>		
Mine Site Technologies	Model TAG IV Transmitter	2G-4162-0
Marco	Model PRIM Model PTT-1	23-A060001-0
Matrix Design Group	Model MatrixTracker T1000 RFID Tag	23-A060003-0
NL Technologies	Model Standalone WiFi RFID Tag	23-A070001-0
NL Technologies	Cap Lamp with RFID Tag	23-ISA0700010
Venture Design Services	MLT Mobile Location Transponder Tag	23-A070003-0
Wholesale Mine Supply	Model i-Q8X rfid Tag	23-A070004-0
Koehler-Bright Star	Model TAG5 Tracker Tag Module	23-ISA0700020
Koehler-Bright Star	Model MultiTAG TP1 Transmitter TAG PCB Assembly	23-ISA0700030
Mine Radio Systems	Model TP2/ISPT	23-A070006-0
American Mine Research	Mine Net Tag	23-A070007-0
<b>Paging/Text Messaging Systems</b>		
Mine Site Technologies	Model PED1	6D-46-0
NL Technologies	Model GII Cap Lamp with Messenger Circuit	23-ISA070004-0
Stolar Horizon	RGU104-001 Remote Graphical User Interface	23-A070002-0

Source: Mine Safety & Health Administration ([www.msha.gov](http://www.msha.gov))

Pillar Innovations' strategy is to exit the mine at multiple points and then tie the leads back together on the surface. "If there's an incident and a portion of the system is destroyed, the rest of the system needs to continue communications and also notify the miners that something has happened," Brenneman said. "The miners that are in by the event will get a notification on their radios telling them something has happened outby and they should switch to a redundant emergency channel. At that point communications are still maintained through a loop architecture."

That makes sense for a shallow coal mine with multiple access points. If there are no multiple access points, then Pillar Innovations' solution is to use multiple entries and separate the cables as much as possible. The redundant path can be hardened to a higher level than the main communication path.

During March 2007, NIOSH awarded Pillar Innovations an R&D contract on the Becker UHF Leaky Feeder system. Pillar Innovations is the system integrator. The purpose of this contract was to do R&D for the survivability of a leaky feeder system. The survivability was divided into two areas: hardening and redundancy. "Pillar Innovations' stance is that the true survivability will be through the redundancy," said Justin Stephens, Morgantown division manager, Pillar Innovations. "If there is a disaster, everything in that entry will be destroyed. Whatever level of hardening we do will not survive. We're banking on the redundancy angle."

The NIOSH contract was broken into three different phases. The first phase was to conduct hardening and redundancy tests and recommend a design. During the second phase, Pillar Innovations was asked to further develop products best suited for this system. Phase

three consisted of the actual in-mine testing, which will take place over the course of nine months. That was slated to start during November 2007 with a full installation at Loveridge.

For the last five months, the Loveridge mine served as the test site with 2 miles of the system installed. "We have a working redundant system," said Stephens. "When the miner is alerted that there is a break in the cable, he is told he needs to go to the emergency channel. If the connection is restored, the miner is alerted that he can return to the normal operating channel."

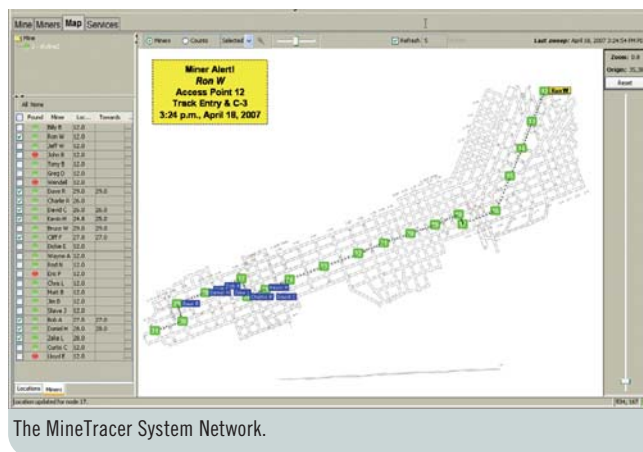
Along with that, Becker has developed a radio tagging and tracking system that works with the leaky feeder system. The miners would wear an active RFID tag and as they pass tag readers they would be identified by the system. "We are also working with Matrix Design Group, which has a tagging system that runs over Ethernet," Brenneman said.

With the S-Miner Act under consideration, neither the mines nor Pillar Innovations knows where the law will eventually stand. "We are doing our best to remain open and scalable," Brenneman said. "When the laws are enacted, hopefully, we will be ready for that." Pillar Innovations was expecting MSHA approval by the first quarter of 2008 and it already had approval from West Virginia OMHS&T.

### Venture Design/Helicomm Tests New Tracking Units

The Big Branch mine in West Virginia installed a Venture Design/Helicomm MineTracer system in January 2007. It is a ZigBee-based tracking, monitoring, and emergency messaging system. Approved by West Virginia's OMHS&T for communications and tracking, the MineTracer is a fully integrated 2-way wireless communication and location tracking system. "We are using a wireless mesh network, which was targeted for low power consumption and large monitoring and control networks," said Ken Hill, director of sales, Helicomm. The low power consumption and subsequent low data rates is the trade off that enables the Venture/Helicomm system to run on a battery backup after an incident occurs.

Radio frequencies do not propagate well underground, Hill explained. Rather than trying to overcome obstacles by increasing power and driving signals, which Hill believes will have minimal affect and drive up power consumption, the Venture/Helicomm system uses many small readers (or reader repeaters nodes) throughout the mine that become fixed access points. The range on the nodes is 350 yards. "They are points of reference, but they are also relay nodes," said Hill. "In an emergency situation, if all else fails, they can find alternate paths out of the mine. The current



The MineTracer System Network.



battery backup is for 48 hours with an option to extend to 96 hours and during that time the operator retains continuous communications, tracking and visibility throughout the installation."

MineTracer provides each of the miners (or the equipment) with either a mobile locator tag or a mobile text communicator. The wireless access points allow people to communicate as they pass through the system. Communications move between the access points wirelessly. All of the data is brought back to a subnet controller, which is attached to a hard-wired connection in the mine office. "As the tags move throughout the system, they will hand off communications from one wireless access point to another," Hill said. The system is limited by a data transfer rate of 250 kilobytes per second (kbps). It can identify the person and the location and some messaging can be embedded, but those messages are limited to 256 pre-canned messages.

The Big Branch mine recently demonstrated the Venture/Helicomm Text Messaging Mobile Communicator (TMC), which is part of the MineTracer system. The TMC enables all equipped miners to simultaneously maintain 2-way communications with the mine office. Unlike voice systems, every miner can communicate with the mine office in parallel, and the digital technology provides a history to include the who, what, where, and when of every message sent or received.

As far as costs are concerned, Hill estimates that the system will cost \$35,000 to \$50,000 per mile, but each mine has its own site-specific conditions. "One of the differences, compared to other systems, is that we are giving continuous coverage throughout the mine," Hill said. "Some of the other systems have choke points at 1,000 ft to 5,000 ft. We are giving the mine precision down to less than 100 ft."

The whole intent of the wireless communications and tracking system is for emergency scenarios, explained Hill. "The level of precision that MineTracer provides will enable the rescuers to pinpoint where their efforts are needed rather than giving a starting point and letting them launch from there."

Venture/Helicomm has submitted the entire system to MSHA and they are waiting for that approval.



Venture/Helicomm's Wireless Access Point (WAP).



## Rajant Proposes a Trail of BreadCrumbs

Rajant Corp. announced in August 2007 that its BreadCrumb wireless system had been approved and listed by the West Virginia OMHS&T. The company's products/systems are now being tested by MSHA. Most of these are Wi-Fi devices that operate in the 2.4 GHZ range. BreadCrumbs are a wireless mesh solution for connecting laptops and voice-over-internet protocol (VoIP) phones as far as 3,200 feet from the mine communications center. The system uses battery-powered, wireless access nodes that enable voice and data communications across a self-healing network. They can communicate with other IP based client-devices such as sensors, video cameras, laptops, video cameras, and satellite terminals.



Rajant's BreadCrumb XL.

Rajant sprang to life as a military and first responder communications company about six years ago. "911 was where it started for our company," said Glenn Booth, vice president-marketing. "We did a lot testing in the tube [the London subway]. That's a tough environment and we had some success running video and voice communications. We published our findings and MSHA contacted us shortly after the mine disasters in 2006. Prior to that, we had never considered mining as a potential market because we had no experience in that area."

About two years ago, Rajant started talking to underground coal mine operators, exploring ideas, and learning some of the nuances of the business, such as intrinsic safety and explosion proof enclosure (XP) certifications. They found a lot of the mines using leaky feeder systems that worked well, but they did not have super high bandwidth. Without that, the mines could not use new applications such as streaming video and mapping data. So the engineers at Rajant thought they should add to the existing systems rather than replacing them.

"We decided to build a BreadCrumbs matrix underground and we knew they needed to be portable, but resilient," said Booth. "These are mesh devices that have multiple wireless paths to get back to the mine office on the surface. If any one node gets crushed or tuned off, there's a way for them to communicate and get back home."

Working with the military Rajant learned two important things: BreadCrumbs have to be tough and easy to operate. Consider special operations in the battlefield, the soldier does not have a degree in networking, doesn't know all the configuration settings for the router, etc. They don't have time for that. "We knew that, if we were going to play in this arena, we have to have all of the intelligence stored in the BreadCrumb," Booth said. "Rajant wrote this software [InstaMesh], a Linux software operating system, and it's built into the BreadCrumb. When it's switched on, it figures out who's connected, who are its neigh-

bors, what's the frequency, what channel, what client devices, what do they look like, are they encrypted or not and make sense of all of that. It's distributed intelligence. They have a map of the world as they see it.

"These devices are very rugged as far as physical attributes," Booth said. Although Rajant currently has no units installed underground, the company has tested them at six different mines.

In theory, the BreadCrumb matrix could be developed in three phases, Booth explained. As the leaky feeder advances with development, there are usually some gaps. The first phase would be to use the BreadCrumbs to fill the gaps. The second phase would involve a gateway between the leaky feeder system and a Rajant (or Wi-Fi) network. Finally, the company would offer intrinsically safe devices that provide communications for the entire mine.

When miners are trapped underground, the mine usually has to resort to drilling to locate them. If the mine suffers a massive roof fall, there would be no connection to the outside world. "With a 4- to 6-inch exploratory hole, we could use a guide wire to drop a BreadCrumb attached to an Ethernet cable down the hole," Booth said. "That BreadCrumb would connect to the existing ones, which would be running on batteries. The battery life could be eight to 12 hours. The exploratory hole does not have to be drilled precisely where the miners are located."

If the trapped miners have VoIP phones, they could communicate with the surface. They could also have RFID tags and the mesh could identify the miner and tell the location. "At a minimum, if all nodes are down except for one, we can identify the BreadCrumb and the location," Booth said. "More than likely, there will be more than one and we can use triangulation to determine exactly where the miner is located, whether he is alive or not."

The system operates by line of sight and that's a challenge with 2.4 GHZ systems. Reflection and multipass are also issues. BreadCrumbs will operate around obstacles, but not with as much bandwidth. The big challenge for the RF world is that, in the lower frequencies, devices become more plentiful but the available bandwidth decreases. Rajant has some new products coming out that will be higher frequency. But, if the mine wants to buy off-the-shelf technology, especially RFID, then this is the appropriate range, according to Booth.

BreadCrumbs can be expensive. "Some of the security features used in military applications can be relatively expensive and it depends on the configuration, but the average cost per node would probably be \$3,000," Booth said. "The range on the nodes is site-specific. In the desert, they can have a range of 7 miles. With line of sight in a coal mine, the range could be as low as 500 ft to 1,000 ft, but that depends on topology."

Rajant has developed the BreadCrumb WE, which is the intrinsically safe node. None of the nodes have been approved by MSHA yet. Currently, Rajant has an agreement in place with Mine Site Technologies and they are discussing partnerships with other integrators to develop other systems.



Rajant's BreadCrumb WE-IS.

## SWS Offers a Wireless Solution

SubterraCom Wireless Solutions (SWS) provides a mine safety communication system built on IEEE 802.11 wireless technology, which includes data and 2-way voice communications, tracking and monitoring. The wireless mesh network infrastructure is composed of decentralized wireless access points that process messages through a low power, multi-hop network by passing packets of information from node to node until they reach their destination. This results in redundant and reliable communications paths from source to destination. If a path stops working due to hardware failure or interference, the mesh network automatically reroutes packets through an alternate path.



SWS Subterra - M8-T.

According to SWS, wireless mesh networks are more accurate, reliable, robust, and expandable than leaky feeder and similar systems; they allow precise monitoring and instant 2-way communication with miners; they can locate miners within 10 meters (with SubterraMine software); and the networks offer virtually limitless reach and dependability, no matter how extensive the mine.

SWS was formed early in 2007 and signed a Letter of Intent in June to acquire iPackets International, which had been in the business developing wireless communications and tracking systems for four years. "SWS is a developer [or manufacturer] as opposed to a system integrator," said Kevin Dickey, president, SWS.

The SubterraMine system is composed of three primary components: 802.11-based Wi-Fi devices, which could be VoIP phones, texting devices, etc.; SubterraVU software, which gives insight into the operation by uploading a map and giving real time dynamic tracking of the miners; and the underground wireless backbone, SubterraZAPs (Zone Access Points). "We operate the client access on 2.4 GHZ range and the backhaul on 5.8 GHZ," said Dickey. The backhaul is the pipeline with which the information is funneled back to the server.

"Our units come with as many as six radios," said Dickey. "Three would be 2.4-GHZ radios with three 5.8-GHZ radios. Six radios would allow the mine to cover up to three entries. In addition to the primary and secondary escapeways [intake and haulage entries], the mine could also cover the belt entry. If the operators want to cover additional entries by having this type of flexibility, it allows them to do so with a minimal number of access points underground."

The range for each device, whether it's a phone, PDA, or a texting device, depends on the signal. "Each mine is different," Dickey said. "The greatest spacing achieved for the ZAPs during

underground tests was 2,700 ft." The ZAPs also have a 96-hour battery back-up.

"This is truly a wireless mesh system," Dickey said. "The system is a true third generation dynamic mesh network. There are different types of mesh networks based on system architecture. By having dedicated back haul features, third generation allows multiple hops without reducing the latency to the point where it can no longer support voice communications. In other words, it is the latest mesh technology available that allows multiple hops with minimal degradation to bandwidth."

All of the SWS devices offer communications and tracking. The M8 Compact (pronounced "mate") is a small tracking device a little larger than a credit card. It allows 2-way communications, meaning that the miner can send an SOS message to the mine office and vice versa. The M8 Text device tracks and communicates. "It has canned messages that the miner can send," said Dickey. "We have the M8 Voice device which has tracking and voice on the first generation, and tracking, voice and text on the next generation. Lately, we offer the M8 PDA which is a fully functional PDA with tracking, voice, free-style texting, and Internet access. One major advantage of our system is that our M8-T, M8-V, and M8-PDA devices provide miner-to-miner communication without the use of a backbone. Therefore, if for some reason the network is down, the miners can still communicate. This versatile product portfolio allows a mine operator to choose devices for different employees; a miner might have the M8 Compact, a foreman and fireboss would carry the M8 Text or M8 Voice, and a superintendent or general mine foreman would have the M8 PDA."

SWS has tested the systems at various operations in West Virginia—not just longwall, but also room-and-pillar mines. The M8 and ZAP devices are currently undergoing approval evaluation by MSHA.



SWS SubterraCom Zone Access Point.

## L-3 Communications Develops Two Systems for the Coal Industry

L-3 Communications is developing two coal mine safety projects under separate NIOSH contracts—a wireless mesh peer-to-peer communications system and an ultra wideband (UWB)-based, real-time location tracking system. *Editor's note: Peer-to-peer means that any node can communicate with any other node without going through a master network.*

In its wireless mesh program, awarded in May 2007, Global Security and Engineering Solutions, a division of L-3 Communications, and its partners are developing a robust, reliable, and survivable communications network which will be tailorable for mines of all sizes and adaptable for use with existing wired mine communications systems. The group recently completed the system design phase of the project and is now working on the system development and demonstration phase which will include a spring 2008 installation and testing of prototype components at International Coal Group's Sentinel mine, located near Philippi, W.Va. Following this phase, L-3 will begin the final demonstration phase during summer

2008 which will involve the full-scale installation and operation of their wireless mesh network within the same mine.

The second mine safety effort, the location tracking program, was awarded in July 2007. For this effort, L-3 and another partner will seek to leverage ongoing geolocation work and commercial off-the-shelf UWB components to develop a unique 'reverse' RFID system. The L-3 miner locating system was recently tested at CONSOL Energy's Enlow Fork mine during December 2007. Currently, L-3 and its partner for this effort are nearing the end of the feasibility testing phase, with system design and component development anticipated during the spring or summer of 2008. Mine testing will continue through the end of 2008.

The L-3 wireless mesh system has multiple access points or gateways to the surface. These are usually located near the shaft bottom or a borehole. The mine would have a primary and secondary gateway and, if the system is compromised, it will reconstitute itself and look for the alternate gateway to the surface. "The system is completely wireless," said Dan Erndle, director-communications engineering, L-3. "The nodes are being developed with an extended range, but range also depends on topography and configuration of the mine."

The NIOSH contract calls for the wireless mesh network to have a 24-hour battery back-up. "We are, however, building the nodes to be compatible with a 96-hour battery as well," Erndle said. "With a 96-hour battery back-up, system developers run into other intrinsic issues with circuitry and hardening. We are working with NIOSH and MSHA on battery hardening requirements and intrinsic safety compliance."

The L-3 wireless mesh system uses a multi-band radio platform which provides improved path loss performance in a coal mine as opposed to WiFi standard 2.4 GHz or 5.8 GHz radios. The L-3 system provides a range advantage, reducing the number of fixed nodes. Additionally, it provides backwards compatibility with legacy leaky feeder systems to provide interoperability and maximize prior equipment investments. "The system provides voice, data and text messaging from the mine operations center to the miner and back," Erndle said. "The design provides full mesh capability with dynamic traffic routing and inherent system redundancy. The nodes are not limited to line of sight operations. At our intended operating frequency we have around-the-corner capability."

The second L-3 mine safety project, the miner locating system, uses UWB technology, a much higher frequency. "With most RFID systems, the tags are worn by the miners or located on the equipment," Erndle said. "What we are providing is fixed RFID tags [either on the roof or rib] and the tag readers are worn by the miners. The tag reader is mobile and the tags are static."

Conventional radio channel frequencies are typically 25 KHZ or 50 KHZ, explained Erndle. With UWB, it's 500 KHZ or even higher. "The energy is spread over a much wider bandwidth, which allows lower power consumption," said Erndle. "It has advantages in the underground environment because normal communications are susceptible to a number of different phenomena, such as multi-path while UWB mitigates much of the multi-path effect."

The RFID reader worn by the miner has a storage capability built into it. "That location information will be uploaded at programmable intervals to a mine's backhaul information system," said Erndle. "We are designing the system to work with existing mine communications systems such as leaky feeder and at the same time be compatible with emerging mesh systems."

Erndle gets excited about early tests, where the location and tracking system demonstrated precision levels within 50 ft and L-3 expects to improve on that. The tags are relatively low cost and they have an eight- to 10-year battery life.

### Tunnel Radio Believes in UHF Leaky Feeder

With 20 years of working with wireless systems underground, Mark Rose, president, Tunnel Radio of America, believes only a certain few methods can be used to communicate instantaneously point-to-point in a coal mine. "When you have one guy at one end of the mine and another at the other end and a third person on the surface, all wanting to use instantaneous 2-way communications, there are very few methods that can be used underground," Rose said. "Most of them involve an active antenna system. Then the mine has to decide on the level of complexity, the handsets, and the frequency band for each application."

Tunnel Radio recently introduced the new TR-155 (VHF) and TR-500B2 (UHF) Leaky Feeder Amplifiers. These amplifiers have both MSHA and West Virginia OMHS&T approval, and represent a new generation in underground wireless technology, according to Rose. "The VHF TR-155 amplifier works with existing yellow radiating cable installations; providing unmatched radio range and power," said Rose. "The TR-500B2 continues the tradition of Tunnel Radio's UHF radio products by providing 'best in class' UHF radio range with many advances, including data and tracking. Both the TR-155 and the TR-500B2 work in competitive leaky feeder systems, are compatible with the company's new MineAx Tracking and Tagging, and are the only systems on the market that are patented and usable on legal U.S. FCC mining channels." The TR-500B2 technology has proven to be a popular system in the West Virginia market, and is not only MSHA approved, but 2006 MINER Act compliant, according to Rose. Already, in West Virginia alone, Tunnel Radio systems are scheduled to be installed in more than 60 mines during 2008.

Tunnel Radio uses two radio bands: VHF (150 MHZ) and UHF (500 MHZ). "Both of them have outstanding characteristics and limitations," Rose said. "Underground wireless communications is a balance of factors. People sometimes mistakenly think that when the radio switch is thrown, the entire mine will instantly light up with communications. It simply doesn't work that way."

To keep it reasonably simple and serviceable, according to Rose, the mine needs to decide where it wants coverage and how complex it wants its system to be. "We do a lot of systems replacement around the country where a group provided a system that was good in the beginning and then no one could service it," Rose said. "We're repairing a system at Skyline now, replacing it with current technologies. We have been around for a long time and we have the technicians to service the systems."

Although UHF has created quite the buzz, Rose believes VHF still has a place. As an example, he cites, Mountain Coal's West Elk mine, which is using a VHF system. "A major part of the mine has the newer TR155 technology and they have fabulous coverage," Rose said. "During the last longwall move, so many people were talking and every single point-to-point communication was being connected that we had to fire up another channel to finish commissioning the system."

Because the wavelength is shorter, Rose explained, UHF may give a few more bounces off the pillars and then on the straight haul UHF will talk 2,000 to 3,000 ft. "At the Dugout Canyon mine, the UltraComm UHF system had a range of 4,000 ft down the haulage and what stopped us was a turn," Rose said. "That's also a





Tunnel Radio of America's MineAx.

7-ft seam. In 40- to 50-inch seams the system will lose half of its strength laterally and longitudinally. Then if the mine height increases, the system will regain full coverage with one cable."

Tunnel Radio tries to offer the mine a very powerful amplifier that's also very current effi-

cient. "With one MSHA IS power supply, we can run about 10,000 ft of system and then we have to install another power supply," said Rose. "That's the best in the business. Flat out—no one else can touch that."

With a Tunnel Radio installation, the cable normally runs along the track haulage. An amplifier network is installed and turned up for a certain amount of coverage. If the mine desires, they can add more. The mine may opt to install a remote UHF MSHA-approved antenna in the intake to obtain 1,000 A to 1,500 on each side.

After extensive field tests in both coal and hard rock mines, Tunnel Radio recently introduced MineAx, a personnel and equipment tracking and tagging system for use underground. Using its comprehensive industrial class software and unique ability to support multiple modes of data transport, including wireless readers (via leaky feeder), MineAx sets the new standard for MINER Act tracking compliance, Rose explained. In wireless mode, the tag readers can be located anywhere within the leaky feeder radio system coverage area, providing easy deployment without miles of inter-cabling.

"For MineAx, we use a military tactical-level protocol and we have been able to run 19 kbps down in the noise where 2-way communications do not exist using that protocol," Rose said. "That allows us to put our readers hundreds of feet off the mainline cable—anywhere the mine wants them."

Workers and equipment can be easily monitored throughout a mine facility via both local and client password protected server interfaces. MineAx is certified by the West Virginia OMHS&T. The industrial software includes many advanced features specifically for personnel and mobile equipment, including a continuous 'first-seen' and 'last-seen' display, a map overlay, plus many other advanced software features.

A directional reader feature tracks the direction of travel within a 50-ft zone allowing "Wireless Brassing" of personnel and equipment moving in and out of the mine. People and equipment can be located instantly underground. All of the wireless multiple mode readers are compatible with the Tunnel Radio's UltraComm UHF and VHF leaky feeder systems.

"Internally, we refer to MineAx as the bird dog," Rose said. "Because if you get into trouble, we are going to find you. The range is amazing."

A directional reader can be placed at any choke point where miners are loading and unloading. It identifies the miner, where he or she is headed, and the state of the miner's battery. "If a miner drives or walks near the reader, it's going to see them if they have an RFID tag," Rose said. "It has very simple deployment and software."

MineAx also has a unique function. "It can obtain directionality within a 50-ft corridor," Rose said. "In other words, if the mine gave

us 30- to 50-ft access around a shaft or portal, we can tell the mine what direction the miners are traveling."

"On the advance, the rescue teams didn't know if they had people buried in front of them," Rose said. "They had to be much more careful with the gathering arms on the continuous miner so they would not further harm a buried miner. With this tracking system, the mine would have a pretty good last known and then the tags act as avalanche beacons, which could speed up the rescue efforts."

The RFID tags are active 2-way tags. "They have two functions," Rose said. "We can upload data to it and that's how we get directionality. We can download data off of it and that's how it acts like a beacon."

UltraComm UHF is approved and Tunnel Radio is waiting for MSHA approval on MineAx. "We have an approved power supply enclosure with battery back up and the reader can go in that unit as-is," Rose said. "We use a common antenna system that is approved. So, once we get tag approval, we are pretty much set."

"We have a new reader/XP box coming out," Rose said. "It's a lower-cost custom made aluminum enclosure. Because we're wireless, it has a dome antenna on it for connectivity to the network. That thing will sit there and track. If all the cables are cut and gone, it will continue to track. We have it programmed to transmit to an alternate path. If a system is cut in half, you can still obtain reader information on the back haul if there's a bore-hole on the back side of the mine or alternate [redundant] cable."

Rose believes that the government should concentrate on approving more UHF portable radios. "We're hoping Motorola gets its two models approved soon," Rose said. "We also hear Kenwood has a second model in for approval. These are reliable, low cost devices. They are serviceable. They have great emergency features, such as man down, worker check-in, the miner can turn them into a pager, they can be pinged to see if they are on and then turn on the microphone. These are common features from 10 manufacturers. UHF is a great solution."



Tunnel Radio's TR-500B2 (UHF) leaky feeder amplifier.

In addition to the \$10,000 to \$15,000 head unit, depending on options, Rose estimates \$3 per linear foot for the entire system. "We are very cost conscience, but a lot of it comes down to the cable manufacturers," Rose said. "Especially with UHF, because the cable is double the price of VHF, but provides five times the coverage—well worth the investment."

"We have been doing UHF for a long time," Rose said. "We have two patents that will be strenuously defended here in the near future. We have always thought that UHF was the solution for the mines and it's going to get interesting here pretty soon."

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