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Digital Networks and Applications in Underground Coal Mines

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DIGITAL NETWORKS AND APPLICATIONS IN UNDERGROUND COAL MINES

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ABSTRACT: An increase in remote monitoring and automation of many aspects of mining operations has seen the demand for more reliable and higher bandwidth communication systems in coal mines.

Digital networks have allowed the convergence of many applications onto a single communication backbone in general industry. The opportunity for a similar consolidation of communication infrastructure has driven the introduction of IP based networks into underground mines. One important application has been tracking personnel and equipment via RFID Tags. This tracking application has in turn formed the basis of a Proximity Detection System or a Collision Avoidance System.

This convergence of technologies is discussed together with the experience in coal mines of the implementation of new applications, including:

- Wi-Fi devices, such as intrinsically safe VoIP Telephones and RFID Tracking;
- Network design considerations;
- PDA's, for paperless reporting systems.

The growing industry push for Proximity Detection Systems and the initial implementation of Proximity Detection Systems, and in the underground mining environment is discussed together with work on a Longwall Tracking System.

INTRODUCTION

The constant push for productivity and safety improvements has driven the development and adoption of more advanced automation, remote monitoring and control systems. The implementation of these systems and successful management of the operation as a whole is dependent on quality communications to and from the underground areas.

Though emerging technologies do need to take into account the limitations imposed by a working environment that is encased in solid rock, Mine Site Technologies (MST) identified the advantages of the so called "convergence of technologies" that digital and IP based communications have been giving general industry and which could offer similar benefits to the underground mining industry.

DEVELOPMENT OF DIGITAL TECHNOLOGY

MST's roadmap was focussed onto a digital technology path about seven years ago, beginning with the development of a digital backbone for underground hard rock mines.

Rather than run a number of separate data backbones, the ability to use an Ethernet based data highway with wireless access through the Wi-Fi 802.11 b/g protocols was an obvious approach to take. This backbone not only provided a significant step change in bandwidth from more traditional leaky feeder systems or copper data networks, but also:

- Leveraged off the optic fibre network some mines had installed but were not fully utilising.
- Provided an optic fibre network for mines that did not have any fibre installed.
- Developed a network topology suited for mines, particularly in ease of installation and maintenance over time. Basically a digital network that didn't need rocket scientists to extend or replace hardware underground.

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- Allowed the use of the many available industrial devices using Wi-Fi and Ethernet protocols, such as PDA's, IP Video Cameras, VoIP Telephones, Lap Tops, basically any Wi-Fi or Ethernet connectable device.
- Through MST's development roadmap not only provided a suitable network but some of the specific devices in a mine worthy form, including intrinsic safe versions for coal mines. These include Wi-Fi RFID Tags, VoIP Telephone handset, and the Wireless Access Point and Network Switch.
- Developed Mine specific applications such as Personnel and Asset Tracking. Other applications included a Vehicle Intelligence Platform for remote, real-time diagnostic uploads, event reporting and alarming, and production cycle monitoring. Then the user interface for the various applications was consolidated into a single web based user software package known as MineDash, for viewing, reporting and managing the digital systems and their respective applications.

Summarising, the development path for the digital systems, now known as our ImPact technology suite, included the digital backbone and specific devices and applications for mines.

In particular the use of digital 802.11 based technology gives an open protocol system with the signal quality and bandwidth to meet increasing levels of remote control and automation planned over the coming decades. This process set the platform for refinement of a general tracking system into a Proximity Detection System (PDS).

Considerable evidence has been presented in the form of statistics by others, including by Queensland Department of Employment, Economic Development and Innovation (Qld DEEDI) during a series of Proximity Workshops in 2009 to clearly demonstrate that people-vehicle and vehicle-vehicle collisions are a major factor in the many fatalities in the mining sector in Australia. These statistics are similar in other mining countries, including the USA and South Africa. Hence the justification for an extra level of risk control around vehicles is well acknowledged. To this end MST has been working with several industry partners over the last 5 years to develop a PDS. Key partners include Australian Coal Association Research Program (ACARP), Xstrata Zinc and Xstrata Coal.

Collision Avoidance Systems (CAS) have been developed, most industry progress has been made in the surface environment, particularly for heavy-vehicle and light-vehicle interactions. This led to MST's decision to focus on their core market in underground mining where no proven or widely deployed system existed.

The development has been in two stages, firstly for hard rock mines and most recently for underground coal mines.

Hard rock mines

As a way of introducing the development of a proximity system for coal mine applications, a brief background development of systems used in hard rock mines is worthwhile. The basic concept is to use active Tags worn by miners underground to be detected by vehicle mounted Readers. The Reader is an existing Vehicle Intelligence Platform (VIP) Wi-Fi enabled data logger module. This VIP module is interfaced to a display unit to alert the driver of a person encroaching within the vehicles vicinity. The Display Unit will also provide the interface between the operator and the system and a means to acknowledge Tags and other necessary controls, such as alert outputs.

Outer Zone – 60 to 120 m:

- Gives a first warning to operator that there is someone around.
- The detection range is roughly adjustable from 60-120 m.
- Importantly, it can detect personnel around corners and blind-spots.

Inner Zone – 5 to 15 m:

- Uses a Very Low Frequency (VLF) magnetic field to give a stable electromagnetic field as the detection zone around the vehicle.
- The detection range adjustable from 5-15 m, adjustable in 1m increments.

- Triggers a higher-level audible and visible alarm.

These two levels of warning are shown in Figure 1.

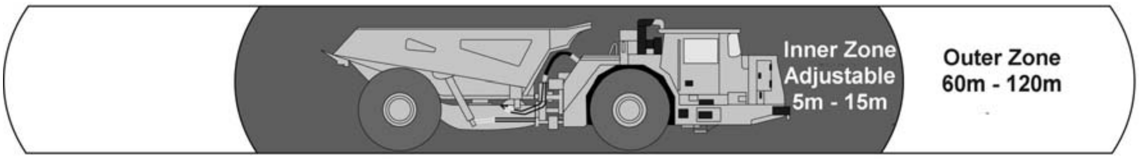

Figure 1 - The proximity detection system is based on two warning zones

The first installed system was at Xstrata Zinc's George Fisher Mine. This involved a staged approach of adapting the technology tested on outbye vehicles in coal mines to the hard rock mining environment.

The project team consisted of a broad range of skills, including:

- Xstrata loader operators
- Xstrata electrical and maintenance engineers
- Xstrata management
- MST electronic and software engineers, communication technicians and project manager.

Coal mines

The on-vehicle equipment used in the hard rock PDS were always going to present a challenge for coal mine certification. In addition, the complex situation and control needed around the mining face with continuous miners and shuttle cars required additional technology development.

Before developing this additional technology MST did a review of other PDS and CAS technologies to determine if a technology existed that could be directly applied or adapted to coal mine requirements. This extensive investigation has led to an alliance with Frederick Mining Controls out of the United States for integrating their HazardAvert® System into MST's overall PDS.

The need for a proximity detection system:

Since the introduction of remote controls in the mid-1980s, the United States mining industry has experienced 31 crushing or pinning type fatal accidents associated with the operation of remote control continuous miners as shown in Figure 2. Remote controls offered increased safety and health benefits to continuous mining machine operators by removing them from the noise and dust exposure of on-board operation, but subjected the operator to new crushing and pinning hazards.

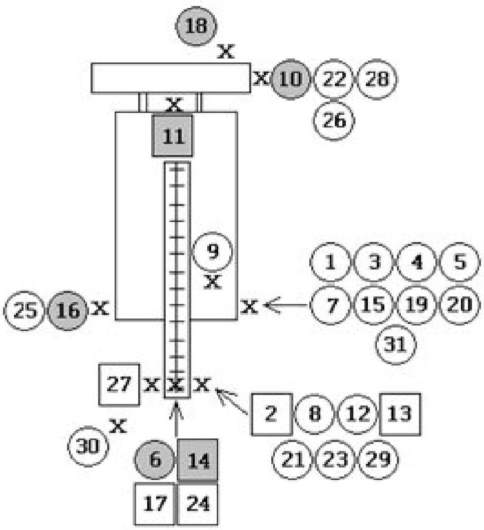

Figure 2 - Crushing or pinning fatal accidents – MSHA Statistcs (Chirdon, 2009)

In Figure 2 the circles represent operators, the squares represent helpers and the greyed areas indicate fatalities during maintenance operations.

"MSHA conducted a review of all mining-related fatal accidents from the last five years. It was determined that approximately 20% of all mining-related deaths could be prevented through the use of proximity detection." (Chirdon, 2009)

The United States' National Institute of Occupational Safety and Health (NIOSH) has complied statistics for "Struck by Accidents" between 2004 and 2008 for underground coal. The data indicates many partial and permanent disabilities (Bartels, *et al.,* 2008).

In Australia 2009 statistics released by the Qld DEEDI revealed that 35% of fatalities within Queensland mines involved vehicle interaction. A sampling of incidents in Australia is highlighted in the Mines Inspectorate Safety Alert 237 (Qld DEEDI, 2009).

HazardAvert® is an adaptation of a PDS which was originally developed by NIOSH-PRL personnel in the US to warn underground coal miners whenever they get too close to continuous mining machines. Since its creation, HazardAvert® has not only been applied to continuous miners but also to Shuttle Cars, Load-Haul-Dumps, Haul-Trucks, Roof Bolters, Drag-Lines, Feeder-Breakers, Light Duty Vehicles, Fork Lifts, and other machinery.

The most important requirement for an effective PDS:

Areas around machinery where injuries have occurred need to be highlighted and marked in some way so that the workers and the vehicle operators are made aware of the danger. The danger zone marker must be robust and should not change, even when in open space or close to coal pillars and other equipment. Marker zone changes would reduce confidence which is not conducive to an effective safety system.

A marker signal in effect is limited to low frequency signals. The frequency chosen must be low enough that it does not propagate. Signals above around 100 kHz start attaching to any piece of conductive material and can propagate for miles. Determining the central focus of a danger marker would be extremely challenging at signals greater than 100 kHz. Low frequency signals can penetrate almost anything, including; coal, rock, dust, water sprays, metalliferous ore, as well as metal. This fact obviously makes low frequencies an excellent marker choice.

The frequency of the marker however must be high enough so that it is out of range of the high energy, low frequency electromagnetic noise always present in mines. The levels of the electromagnetic noise generated can overwhelm the best designed electronic system in close proximity to the source. Fortunately the magnitude of the electromagnetic noise decreases rapidly at short distances from the source. After many measurements in mines near various machines (using a spectrum analyser) 30 kHz was found to be about the high end of expected electromagnetic noise near heavy machinery. Hence, it follows that the best choice for a marker signal would be at the sweet spot between 30 kHz and 100 kHz.

HazardAvert® system components:

The basic system components of the HazardAvert® system are a Generator, a Personnel Alert Device (PAD), and a Vehicle Alert Device (VAD). Other peripheral devices are added depending on the environment in which the system will be used and the type of vehicle to which it is attached. A select group of these components will be described.

A Generator consists of microprocessors, an electromagnetic marker circuit, a warning module, a wireless data link, and can contain a VAD. The Generator is contained in a mine worthy rugged enclosure. There are at least two packaging arrangements for the generator; one an FLP housing (see Figure 3), and the second non-FLP housing for most other applications.

The Generator marker signal frequency is 73 kHz, which is at the sweet spot for marker signals. The size of the HazardAvert® marker field is based on the amount of energy put into magnetic marker field. HazardAvert® can project a marker field up to 30 m from its centre. The size of the field can be adjusted to the requirements of the application (see Figure 4). Additionally, the size of the field can be dynamically adjusted if accurate vehicle speed information can be acquired. This lends its use to mine operations where many vehicles work in close proximity to one another.

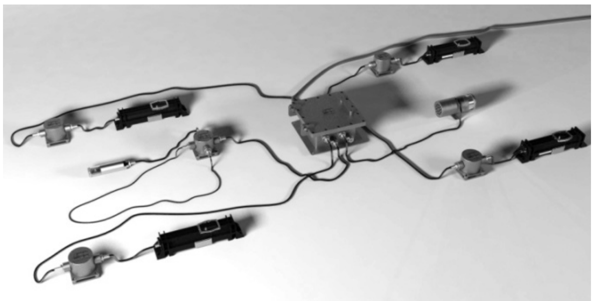

Figure 3 - HazardAvert on-machine components

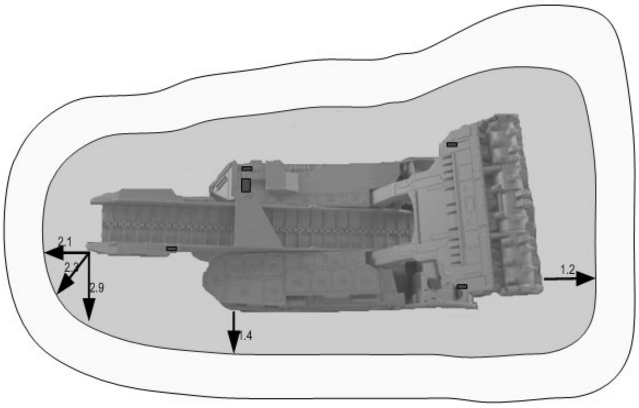

Figure 4 - A number of stable detection fields around a continuous miner form the basis of the HazardAvert® system

Also contained in the Generator is a wireless data link which provides communications with PAD's and other devices. The system warning module is placed within the operators viewing range in the vehicles cab. In many cases, a single Generator can provide the protection needed around a vehicle. Larger vehicles however can be accommodated using two or more Generators.

A PAD is worn by a worker on foot. It is a highly accurate multi-axis magnetic field measurement device with a wireless data link. The magnitude of the Generators magnetic field as measured by the PAD determines the distance to the Generator. The PAD includes a warning module which can be attached to the brim of a hard hat. The PAD is calibrated at the factory to provide a Warning Alert at one distance from a Generator and a Danger Alert at another distance from a Generator. The alerts provided are audible and visual and are programmed to suit the needs of the application. For Australia PAD's are currently being integrated into the ICCL cap lamp.

To provide vehicle to vehicle detection a VAD needs to be installed on all vehicles. A VAD is a PAD integrated into the housing of a Generator. Its purpose is to detect when another vehicle, which contains a Generator, is within its Warning/Danger zone. Subsequently, the operators of both vehicles will be alerted to the other vehicles presence.

HazardAver®t installations:

A number of trials and demonstrations of the HazardAvert® System have been undertaken in Australia, one of the most recent at Anglo Coal's Grasstrees Coal Mine. A longer term trial is also on-going in a hard rock mine, at BHPB's Cannington Mine. However, longer term trials and full installations at coal mines have not taken place in Australia, due to certification still pending. With that in mind, a brief description of the most extensive HazardAvert® deployment to date, at Sasol coal mines in South Africa, follows.

PDS activity in South Africa began with Sasol's ZERO harm mining strategy. A company team was assembled to investigate the risks for workers in proximity of mining equipment and to determine what solutions were available to address the risks. The team created a list of basic performance requirements for the system. The system had to:

- Work on all underground machines;
- Warn all miners and operators of the dangers;
- Slow down and then stop the machine;
- Work with multiple machines with multiple people;
- Have every machine respond to every miner;
- Individually warn every miner;
- Indicate to the operator the highest priority warning/danger;
- Be active with two-way verification;
- Be inherently safe;
- Provide robust marked zones.

HazardAvert® was further developed to meet all the requirements. Of the vendors reviewed, the HazardAvert® system was chosen for trial. The trial was conducted at Sasol's Twistdraai Mine and was concluded in January of 2009,

The Trial Findings (Duvenhage, 2009) were:

- System very reliable
- Equipment damage negligible
- System consistency very good
- No false indications
- Operator feedback very good
- Data collected very useful to address operational concerns
- Interlocks worked very well
- Machine coverage very good
- Dramatically improved overall safety awareness

The success of the Sasol trial resulted in a complete mine roll-out strategy, where approximately 65 working sections are fitted with the HazardAvert® System. HazardAvert® is now on a few hundred underground machines including continuous miners, shuttle cars, load-haul-dump vehicles, and rotary breakers.

Proximity detection and HazardAvert® activity in Australia

MST and Frederick Mining Controls have formed an alliance to integrate the HazardAvert® System into MST's Proximity Detection System. Though particularly relevant for coal mine use, this integration also allows another option for underground hard rock mines where confined area machine control is required.

The status of the activities in introducing the HazardAvert technology include:

- Continuing work with BHPB Cannington on extending beyond the initial trials into a longer term deployment on all vehicles.
- Integration of the PAD into the Integrated Communications Cap lamp (ICCL) to ensure the PAD module is always with a miner underground and part of their Personal Protective Equipment (PPE).
- I.S. Certification of the PAD/ICCL unit.
- Certification of the flameproof components of the on-vehicle devices (VADs, Generators, and Controller).
- Integration of MST's existing Wi-Fi based proximity system with HazardAvert®. In particular incorporating the "Outer Zone" detection system with the HazardAvert® "Inner Zone" detection capability.
- Integration of MST's Vehicle Intelligence Platform (VIP). This will allow real-time reporting of proximity events and alarms via a Wi-Fi communication link with a mine's digital network, where this digital backbone is installed.
- A Functional Safety Assessment to determine and confirm the Safety Integrity Levels (SIL) and Functional Safety requirements for such a system, particularly as the system does have the capability to stop or slow vehicles where required.

LONGWALL TRACKING

Of interest to coal miners is a current project to provide tracking of personnel moving along a longwall face. The need for such a system is being driven by the developments in automation of longwalls and the need to know where people are or, more precisely, that they are in a designated safe location for the remote or automatic operation of shields and face alignment pushes.

MST is working with a longwall manufacturer for the delivery of a longwall tracking system for Narrabri North's longwall. The basic principle is to monitor the location of personnel as they move along the face from support to support. This is done by detecting a RFID Tag worn by each miner (integrated into their ICCL cap lamp). This RFID Tag is already used for general tracking of personnel as they move from surface to underground and through the mine.

For Longwall Tracking a special detection field generator or exciter is installed on each support along the face. This field is very similar to the field used as the "Inner Zone" detection field in the general hard rock PDS. Figure 5 shows the principle of the detection fields along the face that monitor the movement of people to the nearest roof support. However, in the longwall application it is used to raise an alert when a person leaves the field, not when they enter it as in the case of proximity detection.

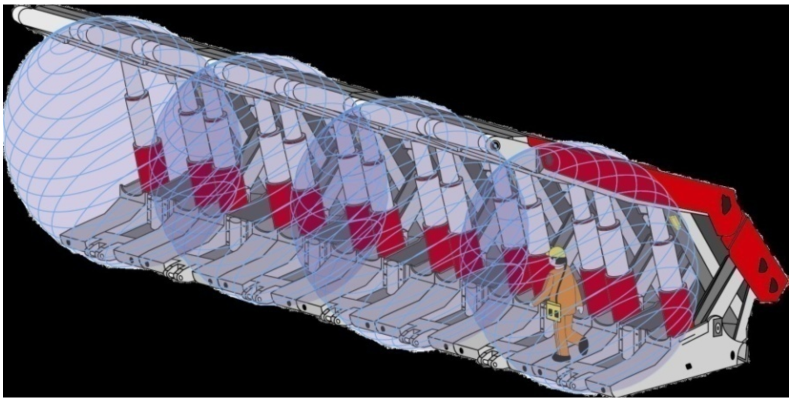

Figure 5 - Longwall tracking

In the Narrabri North configuration, the safe zone is between the supports legs and the rear of the shield (see Figure 6).

Figure 6 - Longwall safe zone

CONCLUSIONS

The development and deployment of a Proximity Detection System has been seen to offer additional levels of control for people-vehicle interactions underground. The benefits of such systems need to be carefully introduced into a mine's current systems and procedures. In particularly their initial introduction should focus on their use as an adjunct to, and not a replacement of, existing procedures. This will ensure their benefits are realised and not compromised by individual complacency and/or de-sensitisation.

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