

Broadband Power Line Communications in Underground Mining

The power of network connectivity for mobile machinery



Challenges for mobile machinery



Infrastructure

By their nature, mobile machines involved in tunnelling and removal of ore operate in a mining environment that has no fixed infrastructure. They tend to be busy work sites with many workers and mobile machinery that is continuously being advanced – often making fixed infrastructure unnecessary and difficult to install



Safety & Productivity

The constant human and machine activity in underground mines makes these areas the most hazardous and the most critical with regards to a mine's production goals and safety requirements. In these and many modern workplaces, data networks are a key infrastructure that underpins high levels of productivity and safety

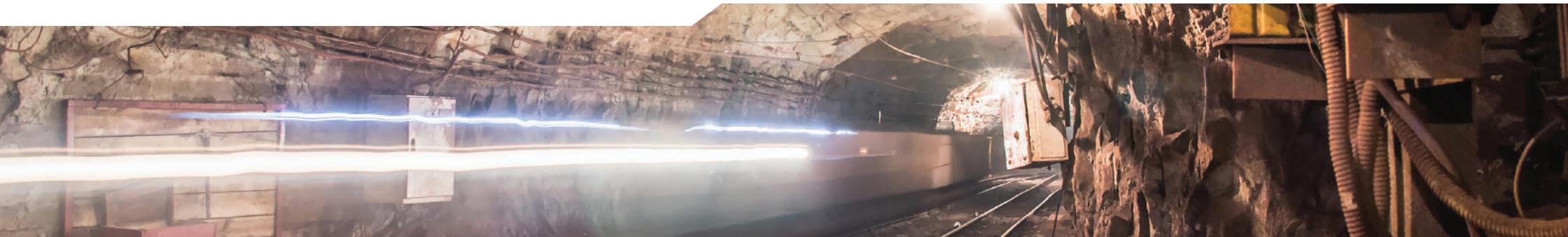


Data & Communications

For underground mining, with its limitations of mobile infrastructure, the provision of data networks to the cutting face has been a major challenge. Some mines still operate machinery that is not connected to the mine network, or send workers to manually collect week-old data stored on memory cards

Use of power lines for mobile infrastructure

In the long term, mobile infrastructure, rather than fixed, is better suited to an environment where the focus of mining activity keeps moving to new areas. Broadband power line communications enable underground mine operators to reap the benefits of continual advances in information technology and has gained wide acceptance worldwide.



What is Broadband Power Line Communications (PLC)?



Data and power in tandem

PLC is a technique for using a power cable to transfer network data in tandem with electrical power. The technology has been around for decades, but has recently evolved into a broadband format that is capable of high data rates of 100 Mbps and up associated with modern industrial data networks. Broadband PLC is standardised technology (IEEE 1901 and G.hn) and operates seamlessly with other network infrastructure.

Broadband PLC is simple to use

- 1 Broadband Power Line Modems (BPLM) are coupled to each end of the power cable
- 2 Each BPLM is also connected to a separate local area network (LAN)
- 3 BPLMs connect the LANs by transparently transferring the network data over the power cable infrastructure

Key features of PLC network technology

- Use of existing power cables
- No fragile parts exposed to the harsh mining environment
- Not limited by line of sight
- Transfers all types of network data
- High data rates



Practical Application

Consider a tunnelling machine that is powered through a 300 metre long trailing cable from a distribution box (DCB). The DCB is located in a safe area and has access to the mine data network. By installing BPLMs in the tunnelling machine and DCB, the data network on the mobile machine is connected to the entire mine network.

Benefits of PLC networks

1 Real-Time Data

PLC networks enable real-time access to operating data of mobile machines from anywhere in the mine network

Modern mobile machines contain control and monitoring systems that rely on a machine-area data network to operate. They are fitted with many sensors to measure the machine's operation and they control high power hydraulic systems and haulage drives.

In highly complex machines, such as longwall shearers, there are hundreds of data parameters involved. Without an external network connection, this data is limited to exist only on the relevant mobile machine. Using a reliable PLC link, the machine data can be made available on the mine network in real-time.

Benefits of gathering machine data in real-time:

- Monitor underground operations from the surface
- Create a database of mining operations
- Examine historical data to determine root cause of faults and for incident investigation
- Condition monitoring of critical equipment to prevent costly and dangerous failures and advanced planning of machine maintenance
- High data rates



Practical Application

Ventilation fans are critical for the safety of workers, especially in mines that experience explosive or toxic out-gassing. Condition monitoring of shaft bearing vibration and motor winding temperature are standard techniques that can detect evolving problems. However, PLC allows remote and real-time access to the data so action can be taken immediately in case of an imminent ventilation failure.

Benefits of PLC networks



2 Production Optimisation

PLC networks enable continual improvement of productivity

Continual improvement is essential for maintaining the competitiveness of a mine and accurate measurement of production operations is the first step in being able to make timely decisions for improvements.

This is a particular challenge for underground mines where independent observation is difficult, shift reports are limited in detail and there is a reliance on the subjective recollections of workers. An accurate and objective picture of mining operations can be built by analysing the raw data collected from mobile machinery.

Real-time data benefits productivity:

- Establish baselines for mining operations and use real-time data and analytics to identify improvements
- Where multiple machines operate in the same area, real-time data can improve coordination between machines
- Production reporting per shift is based on measured data and can be automated
- Operating state of a machine can be inferred from data to reveal how the best operators perform certain tasks
- Artificial intelligence and data mining can extract a deeper level of operational insights from the machine data



Practical Application

A continuous miner can prepare for loading when the shuttle car is about to arrive. Or it can focus on cutting if the shuttle car is delayed.

Benefits of PLC networks

3 Remote Control

PLC networks are enabling the next leap in automation - full remote control

While mobile mining machines have individual functions that are highly automated, they still rely on the presence of human operators to coordinate the overall operation of the machine. The main driver for increasing remote control is the removal of operators from areas with unstable strata and heavy, moving machinery.

The benefits of using PLC networks for remote operations include:

Dramatic increase in safety as personnel are removed from hazardous locations

Machinery can be remotely operated in areas that are unsafe for workers

Mining procedures and operations can be adjusted for increased productivity

Broadband PLC enables an immersive control experience for remote operators

Remote control can be combined with computer control to bring about fully automated mining



Practical Application

Manufacturers of longwall shearers are already testing remote operation using PLC networks to transfer sensor and environmental data to operators and send operator control commands back to the machine.

To enable this level of automation, the machine itself must be fully sensed and it must be fitted with sensors to measure the working environment. These may include:

- **Video and thermal cameras** which would allow remotely-located operators to see progress
- **LIDAR** to produce 3-D mapping of tunnels
- **Advanced sensors** to detect marker bands in the ore body

Benefits of PLC networks

4 Network Services

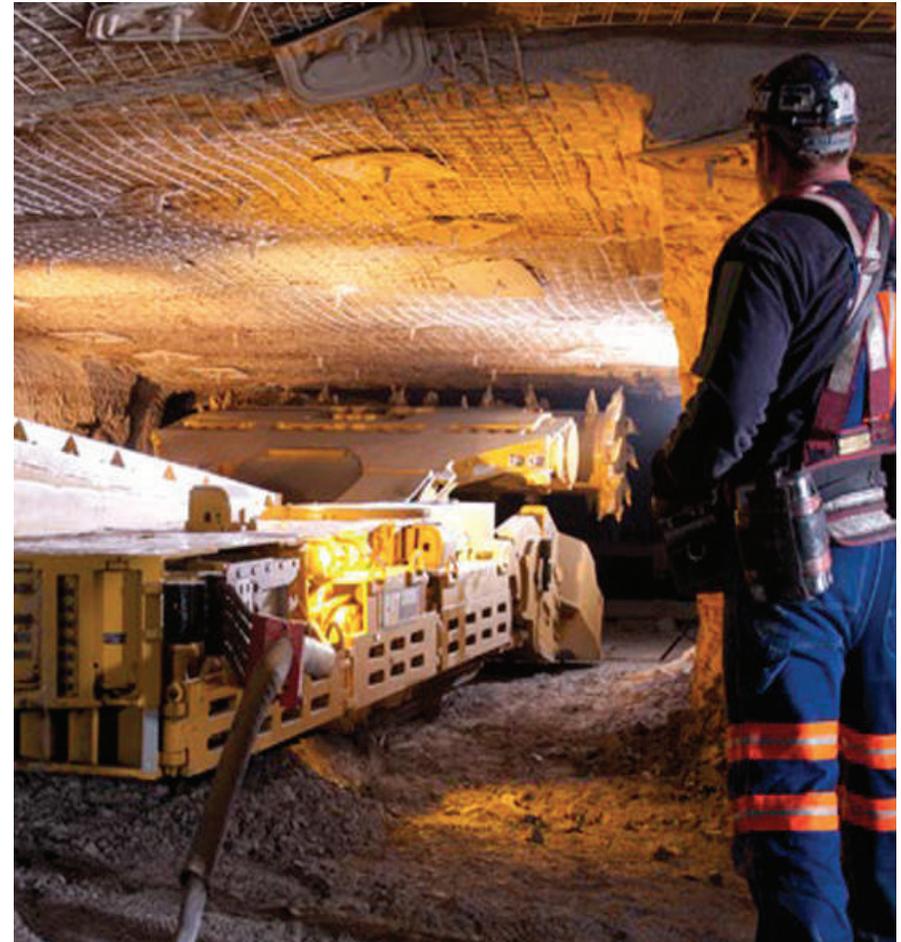
PLC networks enable the full suite of digital services

At its core, PLC is a network technology that brings the power of networks to physical locations that are otherwise un-reachable. High-speed and robust PLC network access allows many services to be brought to mobile machinery and the work areas around them.

Network services that are taken for granted in offices and factories can now be rolled out to underground work locations. This is spurring rapid developments in underground productivity and safety.

Benefits of real-time data:

- PLC networks support all data types and protocols for automation
- BPLM infrastructure on mobile machines supports a Wi-Fi bubble in the surrounding work area
- Voice communications using portable VoIP handsets
- Productivity apps can be run on portable devices at the face and connect via BPLM and wireless infrastructure to the mine network
- Live video streams make it easier for humans to remotely observe underground operations



Practical Application

Personnel detection is a standard feature of underground mining operations and is used prevent interactions between operators and hazardous zones around specific mobile machinery. If the location and identity of workers is made available through the PLC network, it is possible to have an up-to-date and accurate manifest in case of an emergency. Data can be used to create effective rescue plans and messages can be sent to all workers.

Characteristics of Broadband Powerline Modems (BPLM)

1 Adaptive Performance

BPLMs adapt to conditions to provide high data rates and low error rates

BPLMs convert the format of the network data to one that is suited to power cables. The data is broken into small chunks and packed into the one thousand frequency channels of a power line data packet. BPLMs constantly tune each channel to the characteristics of the power cable and any electrical interference.

They have been especially successful in enabling data networks on shuttle cars through:

- Continuous measurement of cable characteristics and interference
- Detection and dynamic adaptation of data transfer for maximum data rate and low error rate
- Automatic and continuous optimisation so there is no need for site-specific setup



Practical Application

Slip-rings on shuttle car cable reels were considered for a long time to be a source of variable signal attenuation and interference to PLC signals. Recent testing at three sites across Australia and South Africa have shown that modern BPLMs can adapt to the variable conditions to provide a stable data link. TCP data rates of 17-45 Mbps are achieved with 270 metre cable and various operating conditions. With the newly available connection from the shuttle car to the mine network, manufacturers and mines are now working to upgrade these simple machines with advanced monitoring and control systems.

Characteristics of Broadband Powerline Modems (BPLM)

2 Robust Backbone

BPLMs are a robust link in an underground mine's backbone network infrastructure

One of the challenges of the underground mining environment is that there is no single network medium that can be used throughout the mine and each one is suitable for specific applications.

The advantage of PLC is that it is an established part of network infrastructure. Its unique mix of characteristics make it a perfect complement to other network media and technologies such as Ethernet, Fibre and Wi-Fi. It's a natural choice when it comes to mobile machinery as it is extremely rugged, has no fragile parts or exposed antennas, and no black spots due to line-of-sight in tunnels.

An essential tool for connecting mobile machines onto the mine network, BPLMs can handle all types of network data and protocols, including VLAN, HTTP, FTP, ModbusTCP, Ethernet/IP and RTSP.

The link they create is part of the mine's network backbone and can be used to further extend the network infrastructure.

Network challenges by mine type

Mine Condition	Open Cut	Underground Hard Rock	Underground Coal
Wide areas	●		
Confined spaces		●	●
No GPS		●	●
Chemical attack		●	●
Explosive atmosphere			●
Weak strata			●
Complex mining machinery			●

Network challenges by technology

Feature	Ethernet	Fibre	Radio	BPLM
Data Rate		Best		
Distance	Worst	Best		
Environmental Survival		Worst		Best
Drop-outs			Worst	
Infrastructure Burden				Best
Mobile			Best	

Characteristics of Broadband Powerline Modems (BPLM)

3 Machine Network

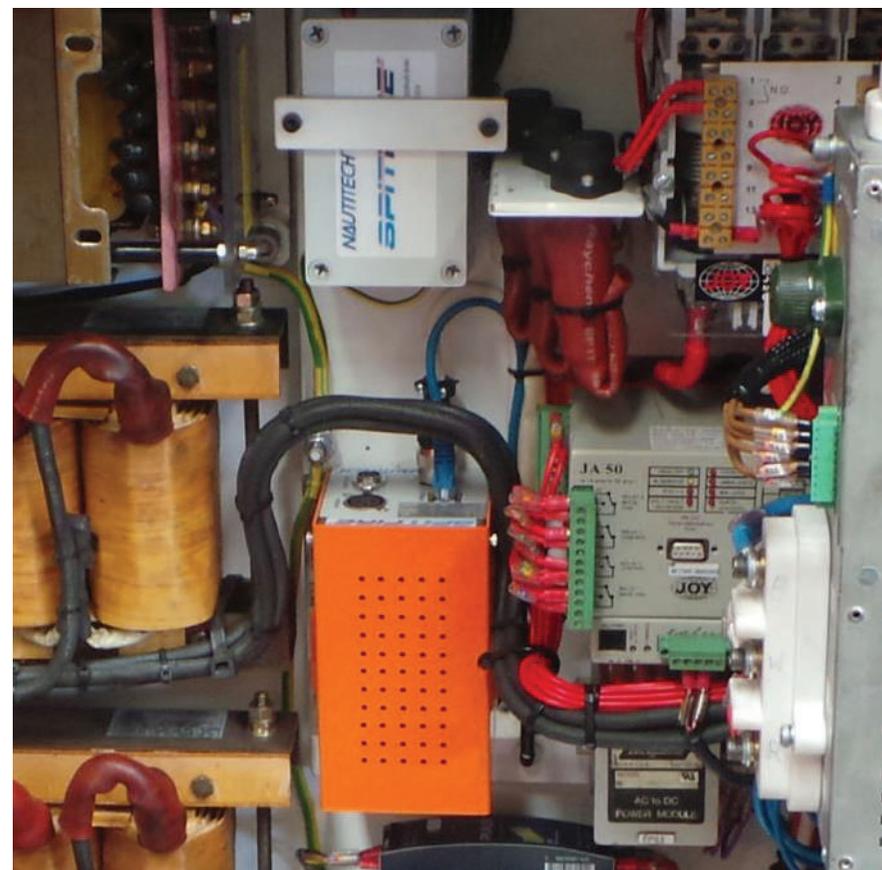
BPLMs can provide a network service over a single trailing cable, or to an entire section of mobile machines

A core feature of PLC networking is that it brings data to every place that is supplied with electricity and takes on the topology of the electrical power network that it is riding on.

In a mine section with many mobile machines, the distribution box (DCB) feeds power to the mobile machines via individual trailing cables. This DCB is also a natural hub for feeding PLC data to all of the connected mobile machines.

Modern BPLMs can:

- Transfer high speed data across a network of power lines
- BPLMs can repeat data over longer distances
- A single PLC network can service an entire mine section



BPLM fitted to a shuttle car at Komatsu



Practical Application

Shearers in advanced longwall mining systems throughout the world rely on a PLC connection over a single cable to transfer large amounts of monitoring, control and video data to a distribution box.

A common practice in Australia and South Africa is to install multiple BPLMs – one in the DCB and one in each mobile machine. This can provide a network service to an entire mine section of mobile machines including continuous miners, drilling and bolting rigs, shuttle cars, feeder-breakers and ventilation fans.

Characteristics of Broadband Powerline Modems (BPLM)

4 Cable Types

BPLMs are proven to work with a wide range of mining power cables

Most mobile machines operate from 3-phase AC power because of the high power levels involved. Voltages range from 415 V to 3300 V, while currents can be as high as 600 A.

A specialised coupler is required to inject the PLC data signals onto the power line while maintaining the required electrical isolation between the high-power power line and the low-power BPLM network equipment.

BPLMs can operate on AC and DC trailing cables, and low voltage pilot cores. They are compatible with earth continuity and other cable protection systems.



Cable Type	Typical Application	Power Supply	Max. Cable Length	Max. PHY Data Rate
3-phase AC + PE	Mobile machines Fixed mine reticulation cabling	400 to 3300 VAC, up to 600A	100 to 450m	40+ Mbps
2-core DC + PE	Mobile machines	550 VDC, 250 A	450 feet	125 Mbps
Internal pilot core	Longwall shearer	None	500+	160 Mbps



About Nautitech® Mining Equipment

Nautitech® is an award-winning global OTM (Original Technology Manufacturer) that designs and manufactures smart electronic solutions primarily for OEMs and underground mining companies

We design and manufacture equipment that delivers **Communications and Visibility**, supports **Automation**, and provides a platform for **Asset and Condition Monitoring** of underground equipment

Our *industry first* solutions are backed by a thorough R&D process

- *First* Broadband Powerline Modem (BPLM) to transfer real-time data from the face
- *First* controllable I.S. headlights and flood lights
- *First* widely adopted methane monitoring and shutdown system
- *First* thermal camera for Group I hazardous areas
- *First* SIL2 compliant methane monitoring solution
- *First* electronic engine management system for longwall relocations
- *First* data analytics for RTVs



**Nautitech's Spitfire
Broadband Power-line
modem range**