Underground Coal Mine Communications for Emergencies and Everyday Operation

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Overview

- Underground mine environment
- Fundamental requirements
- History of USBM Research
- Present state of communications in U.S. coal industry
- Examples of systems
- Discussion

Underground Mine Environment

- Dynamic – faces move >50 ft/day
- Wet conditions, > 90% relative humidity, corrosive water, dust
- Limited line-of-sight due to pillars, undulations, entries following the coal seam
- Potentially gassy (methane, other explosive or toxic gases) – permissibility issue (MSHA)
- Roof may break – entries may collapse
- Every mine presents a unique environment

Wired vs. wireless?

- Wired communication
  - Works well during normal operations
  - Station-to-station + paging phones
  - Wires can get damaged
- Wireless communication
  - More flexibility: Handheld or body-worn
  - Transmission limited by environment
  - Possible damage in explosion or fire
- Combination solutions
  - Best of both systems

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Reliable Communications

- Roof falls

- Fires
- Explosions
- Maintenance
- Power failure – battery?
- Interoperability - Interference

Criteria beyond “simple” two-way voice communication

- Easy portability (“cell phone”)
- Individual addressability (“cell phone”)
- Group addressability (evacuation call)
- Passive location of trapped miners
- Transmission of vital signs (heartbeat)
- Inclusion of remote areas such as bleeders
- Monitoring of sensors and equipment
- Hazard alert functionality
- Redundancy is critical

Permissibility Requirement

- Coal mines are gassy
- Usually Intrinsically Safe (IS) or Explosion Proof (Ex)
- MSHA tests and issues certification
- Additional requirements apply when using communications equipment during emergencies

Communication Signal Paths

- Hard wired – twisted pair, coax, leaky feeder, Ethernet
- Trolley cable
- Wireless – walkie-talkies, modems, repeaters, etc.
- Fiber optics

UG Coal Mines Present Unique Challenges to Radio and Wire Signal Propagation

- Electrical properties of coal attenuate certain frequencies more than others
- Harsh environment presents challenges to design
- Mines are dynamic
- Various interference sources: VFDs, trolley, HV power cables & switchgear
- What works in one mine may not work in the neighboring mine

Where Are We Now

- Physical limits of signal propagation unchanged
- Computerized, digital technology creates “smarter” systems
- Size has become smaller
- Better signal-to-noise ratios
- Improved peripherals (keyboards, displays, earpieces, etc.)

Frequency Selection

- 600-3000 Hertz – best for Through-The-Earth in VF Band
- 300 – 600 kilohertz – excellent parasitic propagation in MF Band
- 27 MHz – very poor propagation in HF Band
- 150, 500, 900 MHz - 2.5 GHz: better for line-of-sight, can turn 1 or 2 crosscuts

Cable Protection Schemes

- Armor or conduit
- Burying
- Borehole
- Loop-Around
- Redundant cabling

UG Wireless Signal Propagation

- Line-of-sight
- Parasitic propagation
- Through-the-earth (TTE)

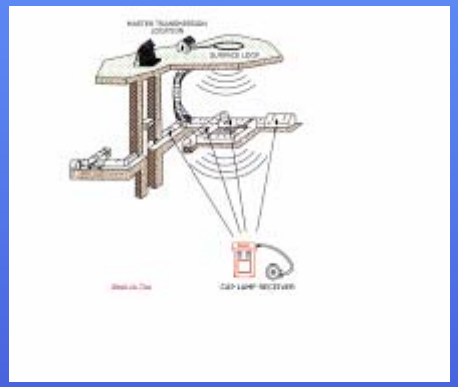
Through-the-Earth (TTE)

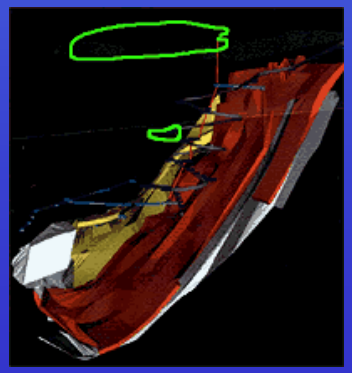
- Requires no cabling between surface to underground
- A portable or person-worn TTE system has advantages over stationary systems

Through-the-Earth Systems

Available

- FlexAlert – 1 way, portable, surface to UG
- PED – 1 way, portable, surface to UG
- TeleMag – 2 way, Not portable





Under Development

- TramGuard-MinerTrack, portable, UG-surface
- Other, mostly similar systems

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Research on TTE

- CSIR Miningtek – South Africa
  - trapped miner location device.
  - 30 meters through rock.
  - Frequency of 2.9Mhz.
  - ID coded belt buckle tag with LED, buzzer
  - Tested in gold mine
  - Portable search unit developed.
  - Commercial availability unknown.

Research on TTE

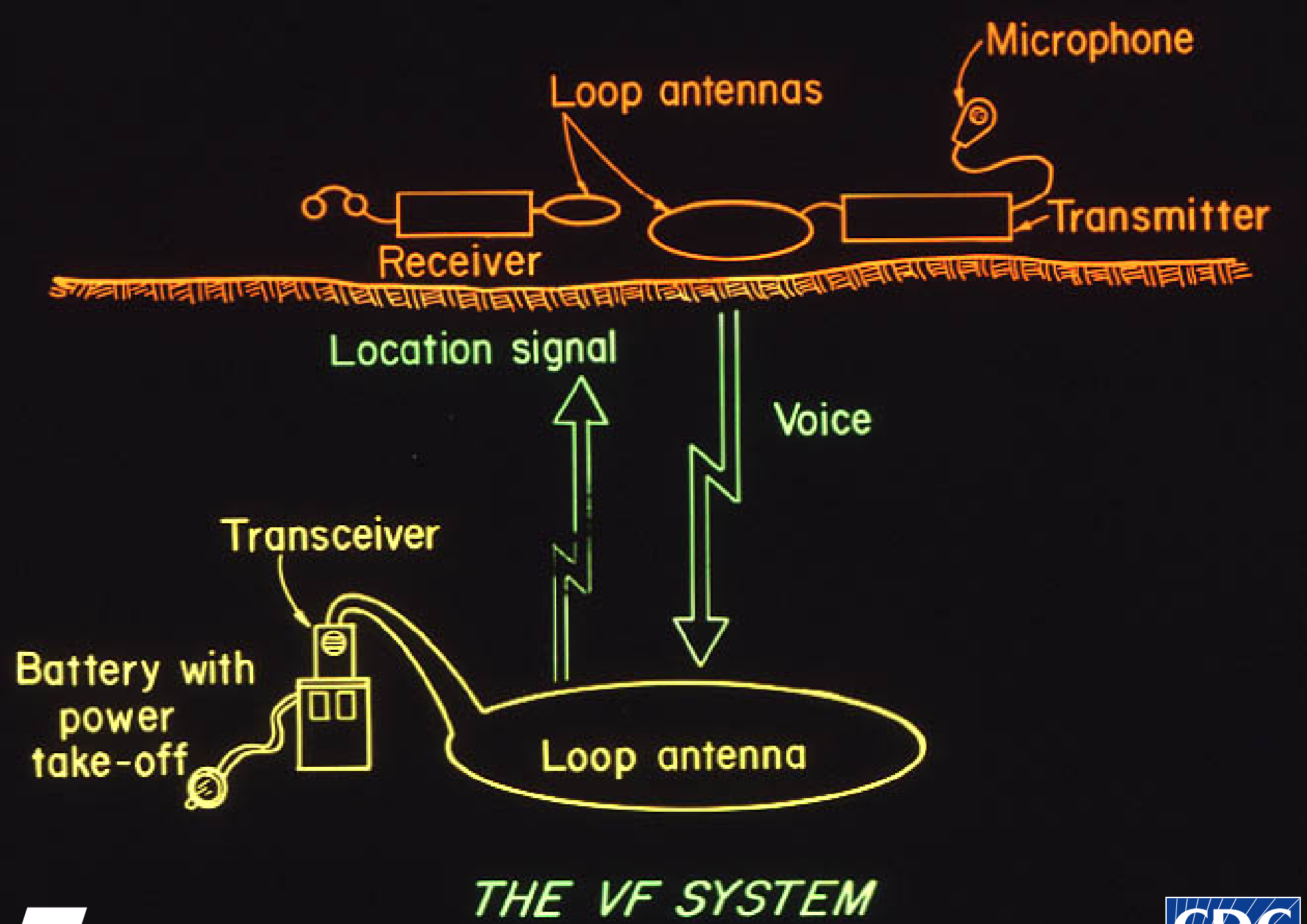
- University of Innsbruck – Austria
  - Beacon contained in a miner's cap-lamp.
  - Frequency less than 10 kHz.
  - Range unknown.
  - Field tested at Schwaz / Tirol silver mine.
  - High accuracy claimed.
  - Commercial availability unknown

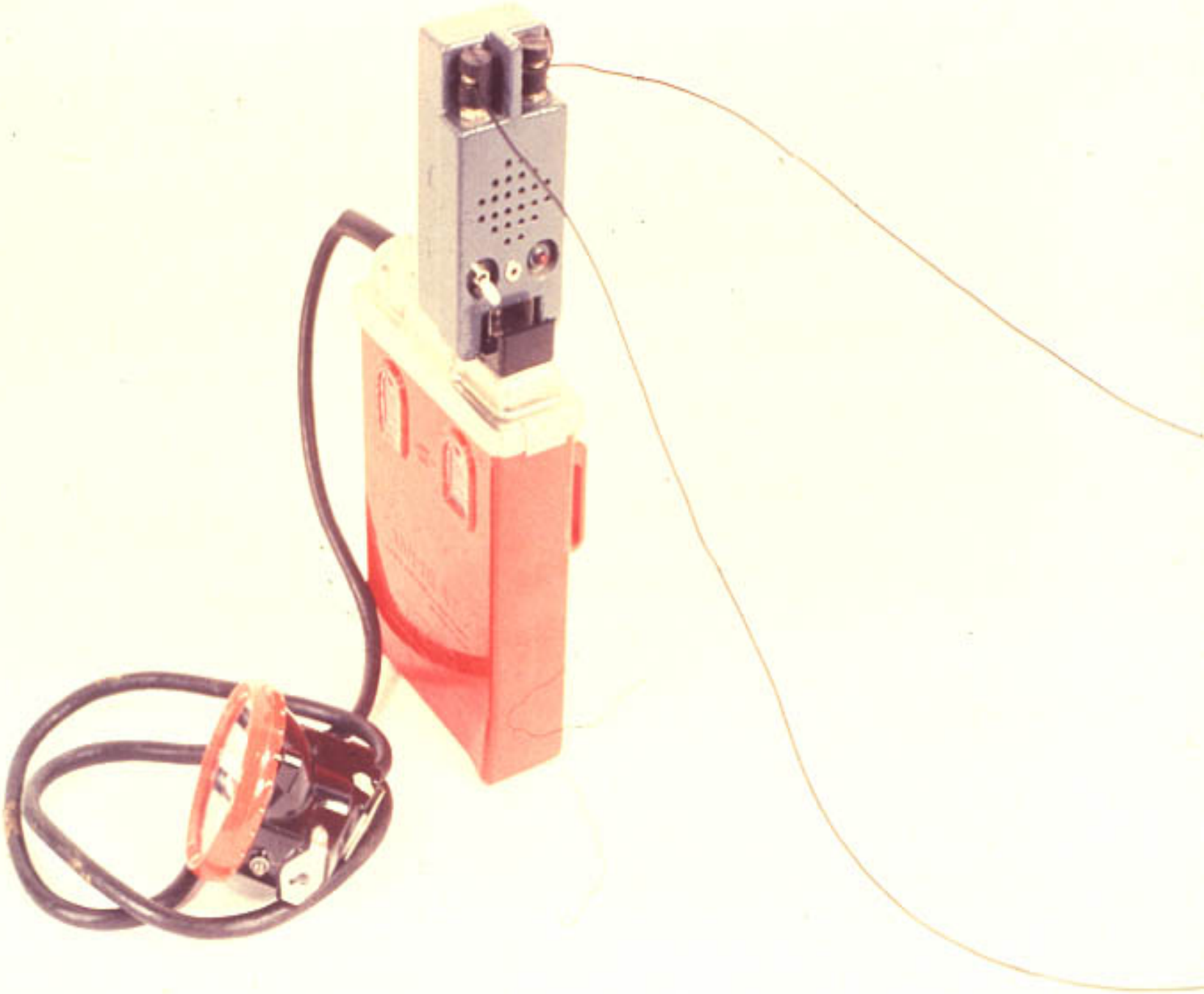
Research on TTE

- Los Alamos National Laboratory/DOE
  - Highly sensitive receiver,
  - Superconducting quantum
  - interference devices (SQUID's)
  - detecting 3 kHz signals to a depth of 600 meters.
  - Field tested at the NIOSH Lake Lynn Laboratory.
  - Commercial availability unknown.

Research on TTE

- U. S. Bureau of Mines – USA
  - Belt-worn beacon and audio receiver
  - PTO on cap-lamp battery
  - Surface handheld beacon receiver
  - Surface voice transmitter
  - Frequency of 600 – 3030 Hz
  - Range – tested to 1600 feet, possibly deeper
  - Tested at 94 mines (documented)
  - Commercial availability: A few companies are using part of the system.


Microphone
Loop antennas
Transmitter
Receiver
Location signal
Voice
Transceiver
Battery with power take-off
Loop antenna
THE VF SYSTEM



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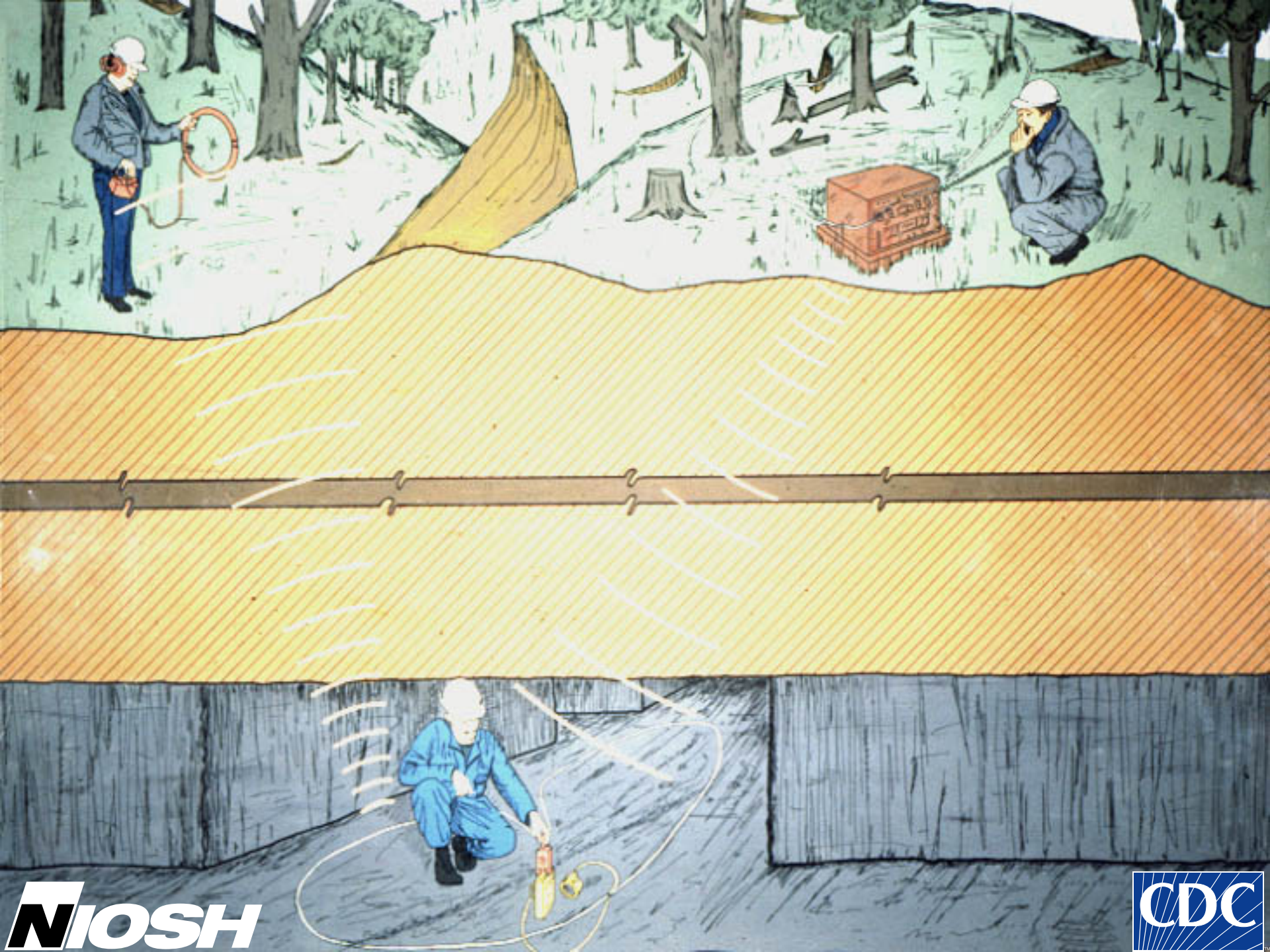

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Other UG Coal Mine Communication Devices

- Telephones
- Pager Phones (Loudspeaking Telephones)
- Trolleyphones and Induction Phones
- Walkie Talkies (in combination with other systems to extend range)
- Leaky Feeder
- Hoist Phones
- Rescue Team Communications
- RFID
- WiFi
- VOIP Phones

Telephones

- Conventional telephone systems
- Widely used
- Rugged and permissible.
- Multiplex over a single pair of wires
- Multiple-conductor cables
- Interface to public phone network (PBX)

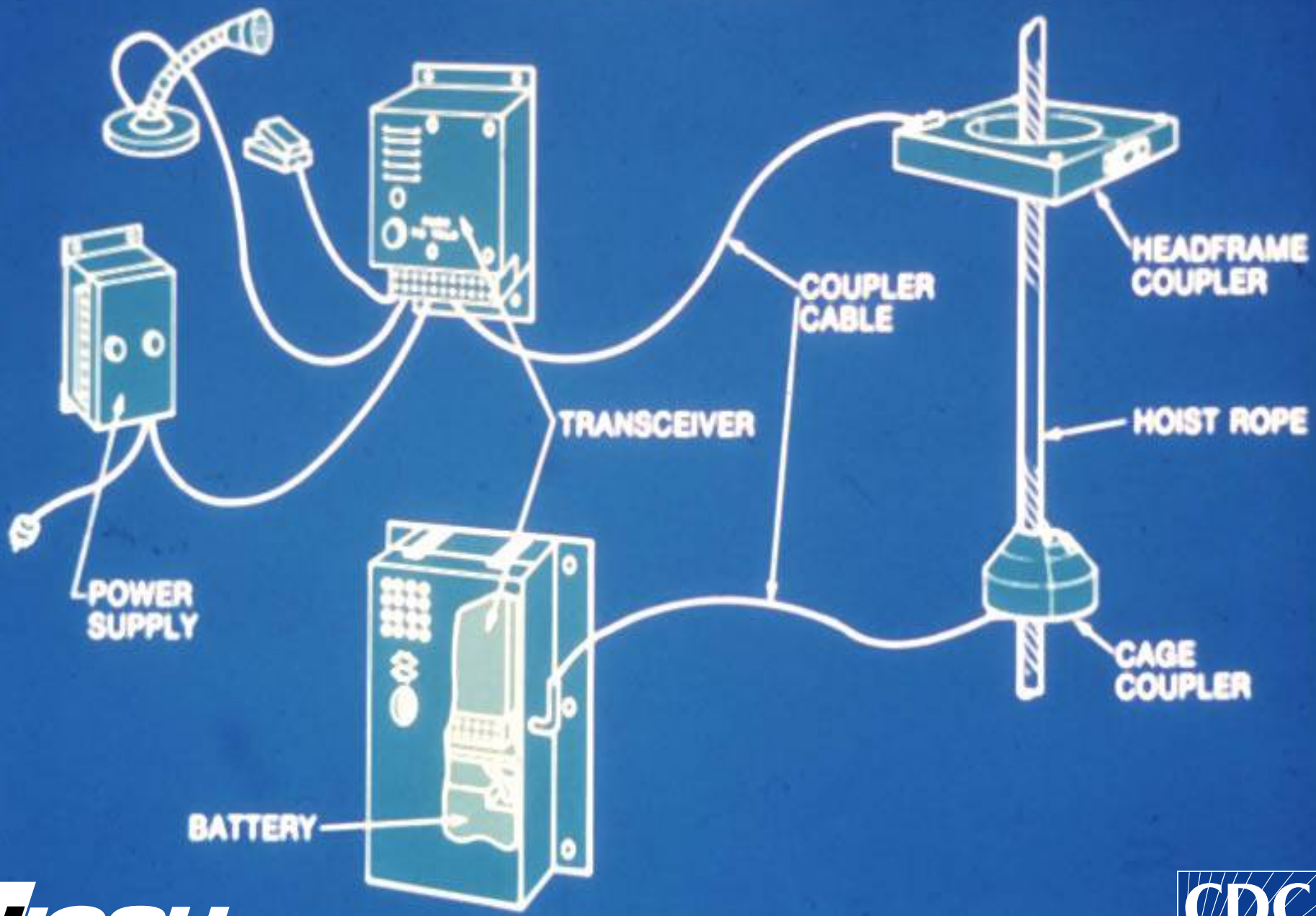
Pager Phones
Loudspeaking Telephones

- Permissible, battery powered
- Use single pair of wires.
- Loudspeaker for paging
- Operate as a party line
- Phone loudspeaker selection through special interface.

Trolley Phones
Trolley Carrier Phone

- Unique to the underground mining industry.
- Still used in many mines with trolley haulage.
- Operate at 60 – 140 kHz using narrow-band FM
- The trolley wire is transmission medium.
- Inductive coupling devices improve range and clarity

HOIST RADIO



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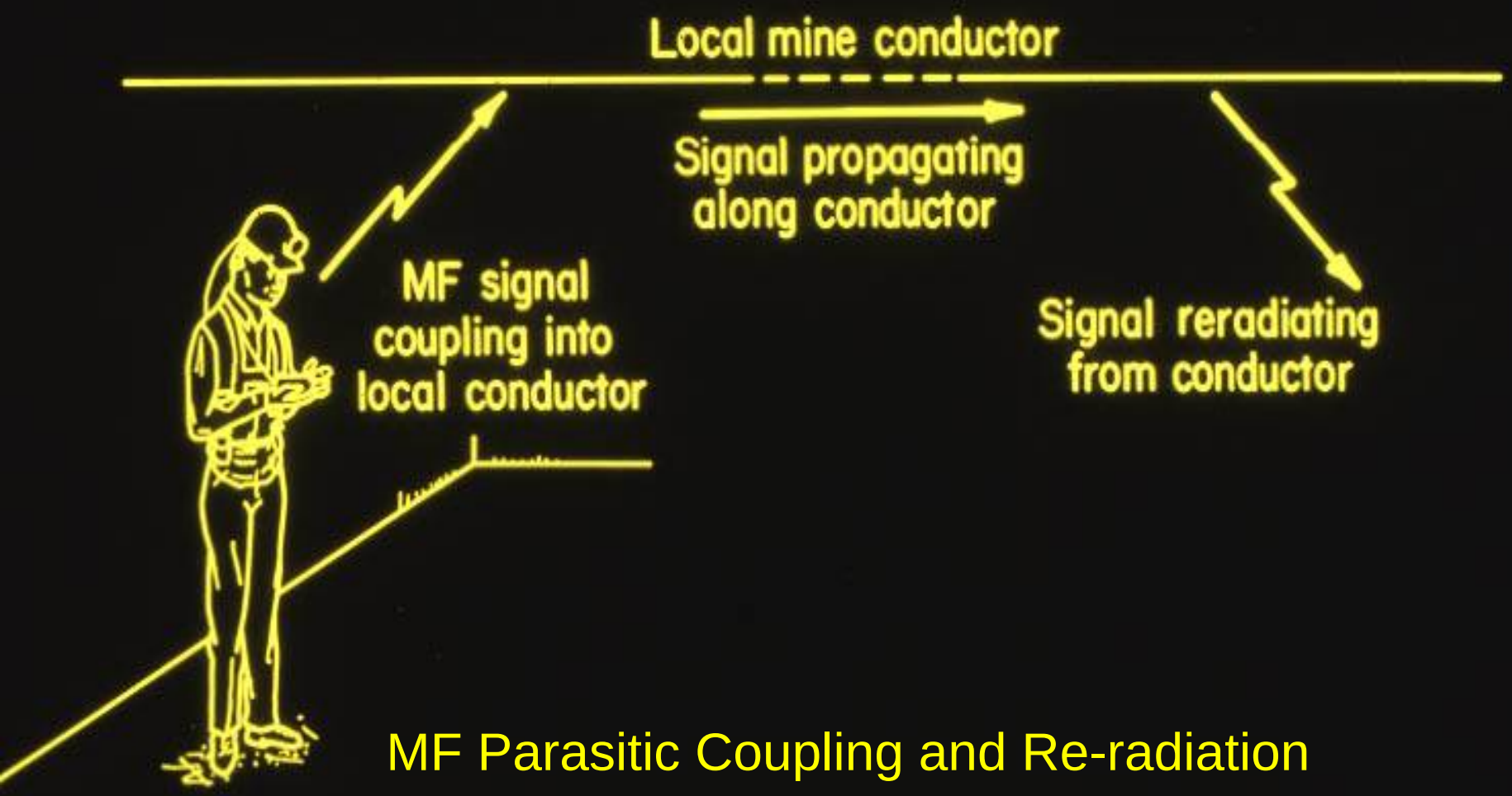
Walkie Talkies

- Conventional
  - Typically VHF-UHF bands
  - Full-mine coverage requires leaky-feeder cable
  - Max. 1000 feet line-of-sight
  - Capable of turning 1 or 2 cross-cuts
- Specialized
  - Unique coupling and propagation properties of medium-frequencies (MF) signals near cables and rails.
  - May operate thousands of feet without specialized cables such as a Leaky Feeder

Leaky Feeder

- Acts as extended antenna for certain radio frequencies
- Cable layout requires specific design
- Signal leaks from cable and enters cable.
- Line amplifiers and repeaters compensate for signal loss
- Power may be limited for permissibility reasons



MF Parasitic Coupling and Re-radiation

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Rescue Team Communications

- Most widely used: sound powered telephone type
- Cable doubles as life-line for team
- Originally developed by US Bureau of Mines (1946)
- Fundamentally unchanged
- More modern systems use MF and VHF technology without direct connection to lifeline

Radio-Frequency Identification (RFID) Tags

- Tracking and accountability
- Persons and assets
- Supported by Leaky Feeder, WiFi, and other wireless technologies

Ethernet (TCP/IP)

- Internet communications protocol
- Widely used for local area computer networks (LAN)
- Increasingly implemented in underground mines
- Employs a special twisted-pair cable, fiber optic or Leaky Feeder cable
- Wireless Ethernet gaining popularity

Wireless Fidelity (WiFi)

- Wireless LAN (WLAN)
- Alternative to a hard-wired LAN
- Airports, hotels, and other services offer public access to WiFi “hotspots”
- WiFi based communications systems are available for underground mine use
- Limited to line-of-sight

Wireless Mesh Networks

- WiFi or other data protocols
- “Hotspots” strategically placed throughout work area
- Hotspot receives, transmits, or repeats
- Redundant network design
- Dynamically reconfigures itself (“Learning” and “self-healing”)
- No predefined signal pathways between the nodes
- Failure of any one node or closure of any one signal path (due to loss of power or an event such as a fire or a roof fall) has little impact on the whole network.

VOIP on Data Network

- Voice communications over a TCP/IP data network
- Special, cell-style, digital telephones available

Cell Phones

- Technology will work in an underground coal mine.
- Wi-Fi enabled phones required
- Requires wired or wireless infrastructure
- Permissibility is an issue
- Technology changes quickly

Interoperability, Interference

- Multiple systems and signal types
- Other systems such as remote control and mine monitoring systems may interfere with communication systems
- Different communication systems may interfere with each other
- Each system must be able to operate without interfering
- RF Interference from HV cables, VFD controllers, DC trolley power and stray currents

System Design

- Look at “big” picture
- Combine different technologies
- Incorporate mine layout
- Perform risk assessment

Summary

1. Wireless Through the Earth
2. Other forms of electronic communications
3. Technology needs updated
4. Past developments may still have merit
5. Interoperability and Interference

Questions or comments?