1. INTRODUCTION

Communication is the activity related to the transmission of signals (data) for the sake of information exchange. In underground mines communication is the crying need both from safety and productivity point of view. Proper and reliable communication systems not only save the machine break down time but also help in immediate passing of message from the vicinity of underground working area to the surface for speedy rescue operation. Therefore, a reliable and effective communication system is also an essential requisite for safety in underground mines. Researchers have been made for improving the technology from the beginning of 20th century. Underground communication methods are lagging behind the surface level communication which is now crowned with 4G technology. The less improved communication inside U/G mine is not only due to lack of interest in this area but also for the unfavorable and hazardous environment.

All existing systems in Underground Mines are based on line communication principle (Wired); hence these are unable to withstand in the disaster conditions as well as formidable in inaccessible places. Non-symmetric mine topology and complex mine structure put further hindrance on the way of line communication. Therefore, wireless communication is indispensable, most reliable, convenient system and must to combat such disaster situations. Frequency modulated (FM) transceivers with directional or active antenna linked with leaky feeder cables and repeater amplifiers at regular intervals can be used for reliable and appropriate mine-wide communication systems for underground mines. The portable transceivers are being used so that it can be carried even in inaccessible places in underground mines. In nutshell, RF communication would be the most suitable and reliable communication system for safety application in the coal mines. It would also help to increase production and productivity in mines.

2. OBJECTIVE

This project report presents a critical review of various intrinsically safe communication systems, mine wide communication systems and web-based information system, instruments used for underground communication. This project report also describes the latest technology, miner information and safety system, system-specific embedded software, and application software. Further, this project report provides the deployment and operation of systems in underground mines. Finally this project report describes a reliable communication system for safety application in the coal mines. It would also help to increase production and productivity in mines.

2.1. NEED OF COMMUNICATION SYSTEM

Underground coal-mining is a dangerous job. Miners work thousands of feet underground beneath millions of tons of rock. They are surrounded by high-voltage electrical lines, darkness, dust and highly explosive methane gas seeps from the coal.

Mine disasters often leave survivors trapped underground. Would be rescuers on the surface of underground who attempt to reach the victims are seriously inhibited in their work by their lack of knowledge of the actual location and condition of the victims. In order to mount an effective and timely rescue effort, rescuers need to have immediate knowledge of the precise location of any survivors and the precariousness of their situation. The nature and urgency of a rescue campaign needed in the case where the miners face a speedy death due to poisonous gas or fire is different from the one in which the trapped miners have an adequate atmospheric environment. Some method of location trapped survivors and communicating with them is essential. However, normal mine communications are usually disrupted by the same disaster that entrapped the miners and are not available to rescuers. Emergency systems of location and communication that can operate through the earth, either from the surface or through the rock and earth material of a cave-in are needed. Such a system must operate under many constraints. It must be reliable under adverse physical and environmental conditions in a mine; it must be inexpensive and portable, it must be built within the “intrinsic” safety limits for mine use and it must be simple to operate. Furthermore, it must produce a signal whose source can be located with precision. We know what happened in Mahabair Colliery on 13.11.1989 where 6 people are killed but 65 miners trapped belowground rescued through a large diameter borehole drilled from the surface. The location of the trapped miners in underground has been provided to the surface via a telephone call from underground to the surface and for which borehole drilled at the exact position.

So, mining industry needs reliable, modern communications networks to continue to improve worker safety and reduce operational costs. These networks must be capable of transmitting voice, video and data throughout the mine. There are a wide variety of important tasks in a mine that need a reliable communications systems, for example, remote monitoring and control of mining equipment, data acquisition for the various sensor networks throughout the mine (e.g. seismic monitoring) and real-time access to mine operating information. The majority of these tasks involve communication with a mobile worker, device or piece of equipment. Meanwhile, miners and their families question why communications systems aren't where they need to be after several disasters in Indian Mines.

3. LITERATURE REVIEW

The Literature Review Reference Report provides background information and context to the main project document. This are-

i. **In Underground Mine Communications**
Mr. JOHN N. MURPHY, SENIOR MEMBER, IEEE, ANDJ HOWARD E. PARKINSON Said, for real-time voice transmission, minimum frequencies are about 30 kHz-in the LF range the higher the frequency the better the coupling efficiency; in the UHF band, the radiated wave propagates in the "waveguide" formed by the mine opening. Hence, selection of optimum frequencies is dependent on the relative efficiency of propagation and the noise level, which together give the optimum signal-to-noise ratio.

ii. **In RADIO FREQUENCY COMMUNICATION SYSTEMS IN UNDERGROUND MINES**
Mr. L. K. Bandyopadhyay, Mr.P.K. Mishra, Sudhir Kumar and Mr. A. Narayan of Central Mining Research Institute, Barwa Road, Dhanbad- 826001, India. Said, In underground mines, sometimes due to fissured strata, the roof or side wall of a gallery collapse, miners gets trapped inside sealed area. Many miners get trapped beneath the big chunk of fallen roof. A communication link between the trapped miner [1, 6-7] and rescue team is essential to find out the actual location of trapped miner for rescue operation. Studies revealed that attenuation of low frequency is comparatively lower through coal block. The low frequency tone signal modulated over RF signal 457 kHz can be transmitted through large thickness of coal block.

iii. **In Rescue and protection system for underground mine workers based on Zigbee**
By Tanmoy Maity, Assistant Professor, Department of Electrical Engineering Indian School of Mines, Dhanbad, India.
Partha sarathi Das, Assistant Professor, Department of Electrical Engineering, Durgapur Institute of Advanced Technology and Management , Durgapur, INDIA and Mithu Mukherjee, Assistant Professor, Department of Electrical Engineering, Birbhum Institute of Engineering and Technology, Suri, WB, INDIA. Said, a wireless sensor network (WSNs) are usually low data rate, low latency and self-organizing is an arbitrarily spaced collection of nodes. A wireless sensor network consist of small devices, called sensor nodes that are equipped with sensors to monitor the physical and environmental conditions such as pressure, temperature, humidity, motion, speed etc. Wireless sensor networks utilize large numbers of wireless sensor nodes to collect information from their sensing terrain.

iv. **In Wireless communication in Underground Mines RFID-Based Sensor Networking.**

Mr. L.K. Bandyopadhyay, Mr. S. K. Chauliya and Mr. P.K. Mishra said that,

A proper and reliable wireless communication system in underground mines will save machine break down time, and also help in immediate transfer of message from the vicinity of underground working area to surface for speedy rescue operation. Different types of wireless communication system are developed, namely, personnel emergency detector, mine tracking system, leaky feeder-based system, induction-based system, very high frequency (VHF)/ultra-high-frequency (UHF) transceivers. Trapped miner locator, etc., and these systems has to be integrated with the required IT system.

v. **Two way Digital Wireless Telephonic Over High-Speed Infrastructure**

By Adcept Technologies pvt. Ltd. said that, generally, wireless broadband refers to technologies that use point-to-point or point-to-multipoint microwave in various frequencies between 2.5 and 43 GHz to transmit signals between hub sites and an end-user receiver. While on the network level, they are suitable for both access and backbone infrastructure, it is in the access network where wireless broadband technology is proliferating. As a consequence, the terms "wireless broadband" and "wireless broadband access" are used interchangeably.

vi. **In WIRELESS COMMUNICATION IN U/G COAL MINES, MR. RAKESH ROUSHAN said that,**

Accidentsduetorooffallandcollapseofsidegalleryaresomeofthedailyoccurrencesincoalmines.Hence the wireless communication offers an aid to establish communication with the miners, trapped under coal debris.

•To meet the intrinsic safety criteria for hazardous zone (Indian Standard, IS5780:2002), the power restriction of transceiver to be used in underground mine is 2W, which further limits the communication range. Therefore, it is important to find out the suitable frequency, which is attenuated the optimum when passing through strata and a suitable model for implementing the same. This will ultimately help in designing appropriate trapped miner locator and other wireless communication devices for underground mines.

•Wireless communication systems will also open the door for endless possibilities so far applications and intelligent solutions that can be used during daily operation like real-time tracking of mine machineries and equipment's, devices controlled by centralized control interface and much more.

vii. **In Journal of Scientific and Industrial Research**
Vol. 67, January 2008, PP. 28-35
Modernization of Indian Coal Mining Industry: Vision 2025
Mr. S.K. Chauliya, Mr. L. K. Bandopadhyay and Mr. P.K. mishra of
Central Institute of Mining and Fuel Research (CIMFR), Dhanbad 826001, said that, a proper and reliable wireless communication system in underground mines will save machine breakdown time, and also help in immediate passing of message from the vicinity of underground working area to surface for speedy rescue operation. Different types of wireless communication system developed. Namely, personnel emergency detector, mine tracking system, leaky feeder based system, induction based system, very high frequency/ultra high frequency (UHF) transceivers, trapped miner locator etc. and those systems will be integrated with the proposed IT system.

viii. **In International Journal Of Emerging Technologies in Computational and Applied Sciences (IJETCAS)**
Hybrid Wireless Communication System Using ZigBee and Wi-Fi Technology In The Coalmine Tunnels Mr. Alfiya Shaikh of Trinity College Of Engineering and Research , Pune. Said that, Current monitoring system in underground mine were cable based which play a key role in safe production. However, these systems have some disadvantages for coal mine monitoring. It is inconvenient to dispose in many areas such as abandoned laneway and exploiting areas for the trouble reconnection. But just in these areas, they really have a lot of danger. To overcome shortcomings of wired systems, people proposed the Wireless Sensor Networks (WSN) to implement the wired monitoring system. But the WSN has its own limitations, such as not having enough bands to communicate and transfer image data efficiently. So, how to overcome the limitations and provide one communication system with wide band is concerned.

The remainder of the article is arranged as follows. The next section we discuss the choice of working frequency for the wireless systems and the node deployment. Then, we introduce the wireless system that we invent using ZigBee and Wi-Fi technology which can satisfy the requirement of coalmine need.

ix. **RECENT TRENDS IN COMMUNICATION SYSTEMS FOR UNDERGROUND MINES**
By Dr. Singam Jayanthu* and Singam Jayadarshan***
Professor, Mining Engg Department,
National Institute Of Technology, Rourkela- 563117
**** B Tech Student, Electronics and Communication Engg. Dept,**
Sikkim Manipal Institute Of Technology- Sikkim, 737136 said that, various types of communications systems useful for underground mines are shown in Fig 1.

Conventional systems or the wired system is comprised of magneto phones, paging phones, voice powered phones etc. Magneto phones are the oldest crank ringer phones of 20th century operated by DC batteries and AC signals. Paging phones are partly line wired phone for voice communication with no tracking capability. TTE or Through the Earth system is a well-known system providing alarming, tracking and messaging with the help of loop antennas on surface of mine which transmit low frequency signal to receivers, integrated into cap lamps. Whereas wireless network system deals with Wi-Fi (IEEE 802.11), Bluetooth (IEEE 802.15) and WiMax technologies. UWB (ultra wide band) system is the radio system for short range communication with very low power at a very high data rate (very high band width). When high voltage trolley line is used as signal path only for voice communication then it is called as the trolley carrier phones system. Hoist rope system is nearly same as trolley carrier phones except that the hoist radio signal is inductively coupled to hoist rope(i.e. use of capacitor as coupling device in the case of trolley carrier phones). The well-known Leaky Feeder system is comprised of leaky feeder cable and amplifier boosters for two way voice, data and video communication utilising the leakage field of the cable. A hybrid RFID system is used for tracking of miners throughout the mine by the help of Radio Frequency chip or tags worn by miners or installed in any large mining machines. Seismic system is another kind of portable system using seismic monitoring sensor on the surface to detect sound generated by trapped miners.

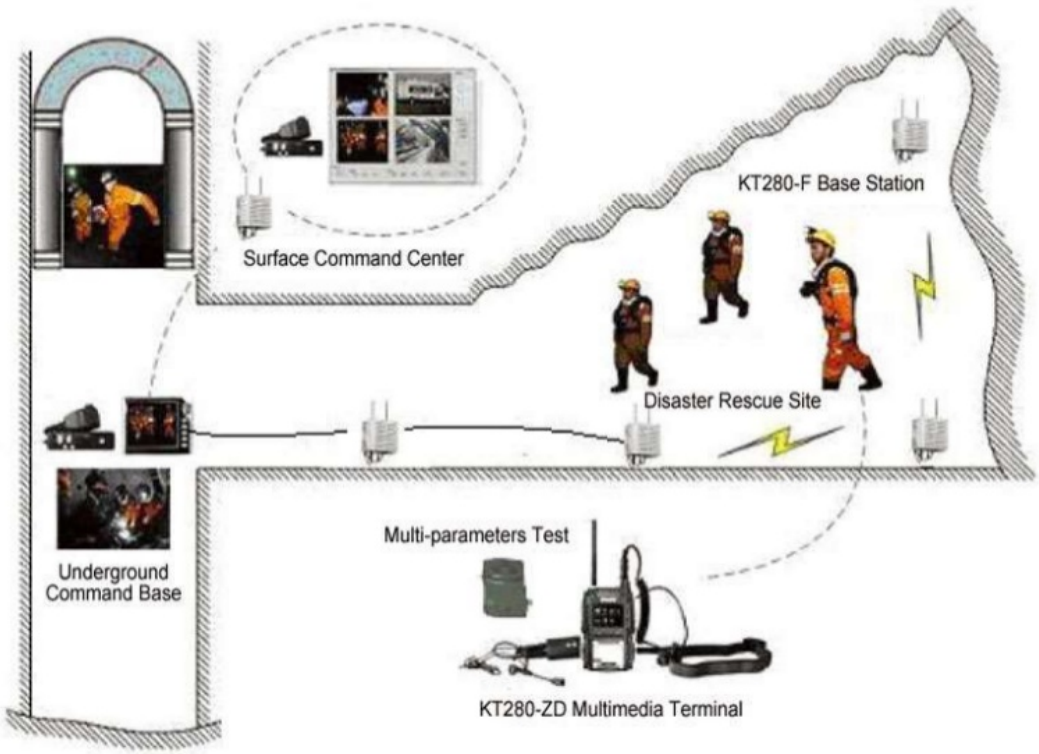
x. **COAL MINE COMMUNICATIONS, Writers Institute for Occupational Safety and Health (NIOSP) Pittsburgh Research Laboratory's William H Schiffbauer and Jurgen F Brune. Said that,** present communications systems for underground mines can be hard-wired or wireless. Both types of systems can fail when faced with fires, roof falls, explosions, and power or battery failure. Currently installed wireless communications systems usually employ a special antenna cable called a "leaky feeder Fiber optic cables are also used in some applications to form a "backbone U for wireless transceivers. Through-the-earth (TTE) and wireless radio systems are less common. Except for TTE systems, most wireless systems require some wire-bound components, which are susceptible to failure during disasters as cable breakage interrupts communications.

These reviews were undertaken to identify how legislative mechanisms, technical approaches and applied management strategies are used in regard to assessing and responding to impacts of Wireless Communication.

I had gone through several books, Journals papers, Internet, Wikipedia and found, that the main reasons of success of wireless communication system at Underground mines in USA, South Africa, Canada, Australia are,

- The policy trust of coal sector.
- Massive investment
- The focus on "walking on two legs".
- Fact decision making
- Highly modern equipped Laboratory
- Highly developed manufacturing base for mining equipment's and
- Above all the work culture in a mandarin-dominated society.

  These critical success factors are simply missing in Indian Coal Industry resulting in poor performance.

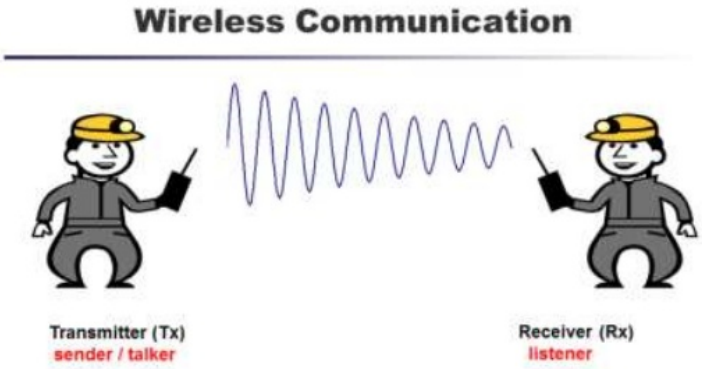


4. FIELD STUDY

The communication in Shyam Sundarpur Colliery, Bankola area, Eastern Coal Fields Limited is primarily based on CDS, signaling or telephone system. Telephones are located at strategic points in 2no. Pit, and 3no. Pit. This system has the inherent limitation as Wires are to be laid to the specific points and a direct two-way communication is not possible. Advanced wireless communication technology for direct communication from surface to underground and vice-versa may be a better alternative. The advanced communication system able to transmit voice, data, video-telephony, real time production information and track machinery and personnel deployed in the underground.

5. SUGGESTIONS

The communication system needed in Shyam Sundarpur Colliery is **Wireless communication system**. As Shayam Sundarpur Collliery is Hundreds of feet underground, nearly a mile away from the mouth of the mine, a miner realizes he needs to repair a key piece of equipment. Summoning an engineer used to mean a long walk back through the mine or a long wait for the man trip, a motorized shuttle vehicle. While the miner is walking or waiting, no coal is being dug, so these interruptions add up quickly in lost production. But now, with the push of a button on a wireless VOIP handset, miners can request that engineering resources be dispatched to a location without going anywhere. If the VOIP system is connected to the public phone network, staff in the mine may be able to get service assistance from equipment manufacturers while at the working face. In a few minutes, the miner is safely and productively back to work. Multiply this scenario by dozens or hundreds of times per week in a large mine, and there is an obvious, immediate positive impact to the bottom line.



5.1. WIRELESS COMMUNICATION

Wireless communication is mainly comprised of transmission of data from the sender to receiver which may be in groups or from a miner to another miner, in which transmission deals with the amount and speed of the data using electromagnetic waves. The information from sender to receiver is carried over a well-defined channel. Each channel has a fixed frequency bandwidth and capacity (bit rate). This seems very simple above ground , as a huge amount of data can be sent at a very high data through cables or optical fibers, which can be conveniently installed, in which noise can be easily eliminated without using any special techniques.

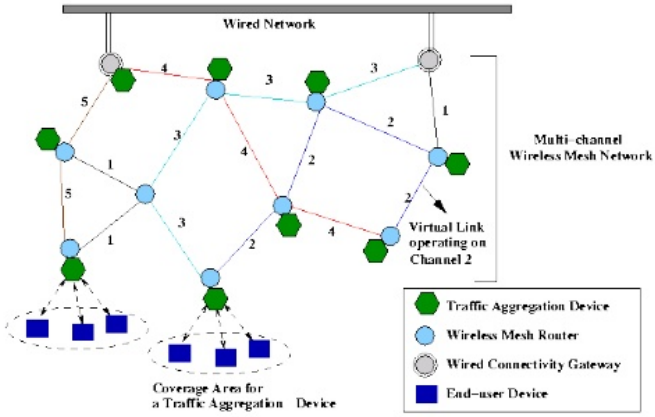
5.2. PREVIOUS PROBLEMS IN WIRELESS COMMUNICATION

Radio wave propagation for wireless communication through underground coal strata suffers from dispersion, absorption, scattering, and attenuation of waves due to its natural properties and space limitations. The heterogeneous and complex structure of coal and rock strata further complicates the process of radio propagation. The attenuation of signal mainly depends upon the dielectric constant and conductivity of coal strata. The dielectric constant of different types of coal available in Indian underground mines is given below. The conductivity of coal varies from 10-8 to 0.02 mho/m depending upon the physio-chemical properties of the coal.

Type of Coal	Dielectric Constant
Anthracite Coal	3.2
Bituminous Coal	2.8
Coal Dust	2.5
Coal with 15% moisture content	4.0

5.3. HERE THE SOLUTION FOR WIRELESS COMMUNICATION.

Traditional cellular signals don't propagate through rock, and there's no time for laying wire phone lines that might be damaged by rock falls and moving equipment. The answer is third generation wireless mesh technology based on the Wi-Fi 802.11 protocol. A series of multi radio enclosures, called wireless mesh nodes, propagate the signal down the length of the mineshaft and wirelessly connect miners working or traveling nearby. The nodes may be placed along entries, travel ways, beltways or in airway intakes and returns to wirelessly link miners at the working face to the rest of the mine, as well as to the office and managers outside the mine. Wired communication in fails in situations where connectivity is imperative e.g. fire outbreak, roof fall, power or battery failure, explosions etc. This is the reason; wireless communication has a key role in underground mines.



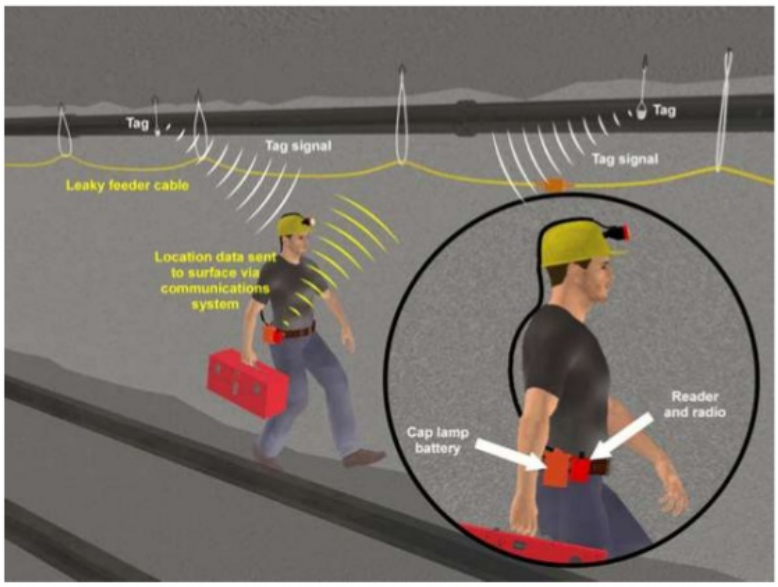
Besides the time-saving productivity boost, the wireless mesh nodes also provide infrastructure that delivers lifesaving miner location and communications capability in case of an accident or disaster. Preserving the safety of underground mine personnel has been an important focus of government and industry. A wireless communications system that provides two-way communications between underground and surface personnel and an electronic tracking system that allows surface personnel to independently determine the location of anyone trapped underground is key to meeting the requirements. New Wi-Fi wireless mesh technology delivers high performance and reliability at low cost over long distances in underground coal mines in numerous pilot and production mine networks, because it allows for reliable two-way VoIP communications and Wi-Fi location tracing. Mining network communications and tracing supplier Active Control Technology (ACT) of Burlington, Ontario, Canada, has installed wireless mesh technology supplied by Mesh-Dynamics in a number of mines.

5.4. Needed Communication techniques at shyamsundarpur colliery to improve safety and production of the mines are:-

a. Straight gallery communication
b. Mine-wide communication
c. Trapped miner communication
d. Personal Emergency Device System

5.4. [a]. Straight Gallery Communication:-

Radio system covers voice communication within the underground mine, in the ultra-high frequency (UHF) band, attenuation is relatively low in the straight mine entries and is significantly higher when the signal propagates around a corner or when a massive piece of machinery is in the path of propagation. At frequencies in the range of 200-4000 MHz, a coal mine tunnel act as a low-loss dielectrics and dielectric constants in range of 5-10. An electromagnetic wave travelling along a rectangular tunnel in a dielectric medium can propagate in any one of a number of allowed waveguide modes. All of these modes are lossy modes because any part of the wave that impinges on a wall of a tunnel is particularly refracted around the surroundings and partially reflected back into the wave guide. The refracted part propagates away from the wave guide and represents a power loss. The attenuation rates of the waveguide modes depend almost entirely on refraction loss. The overall loss in strength, in a straight gallery, is the sum of propagation loss and the insertion loss of the transmitting and receiving antennae. It has been found that the total loss is minimal in the range of about 450-1000 MHz, depending on the desired communication distance and tunnel dimension.



[a][i] **Leaky Feeder system:-**

Becker's new generation in-line leaky feeder amplifier has been designed and manufactured in South Africa to make underground communication more effective and reliable. Remote diagnostics and Cable Length Compensation (CLC) ensures installation and system maintenance is a simple process. Interchangeable filters allow the amplifier system to be upgraded from VHF to UHF to GSM.

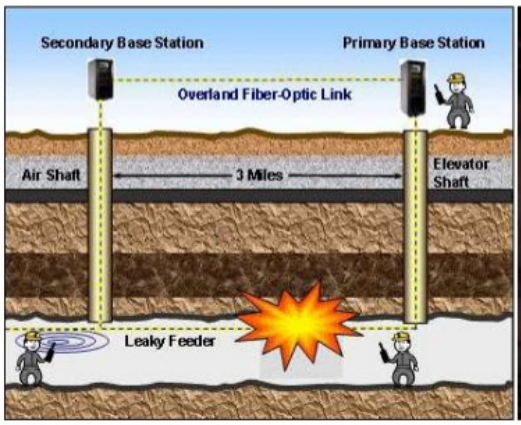
The Leaky Feeder system features

- Proven Mine-Wide communications
- Remote Diagnostics
- Easily expandable and easy to maintain
- Cost effective
- Multimedia: Voice, Video, and data
- Integrate with fiber optic backbone
- Supports off-the-shelf equipment

Applications for Leaky Feeder

- Mine Wide Voice communication network
- Medium speed mobile data
- Distributed control and monitoring network
- Local/Portable video monitoring
- Wide area antenna coverage

This communication highway operates from a single Leaky Feeder Cable that acts as a mine-wide antenna. It eliminates the need to install and maintain dozens of hardwired cables and signal wires.

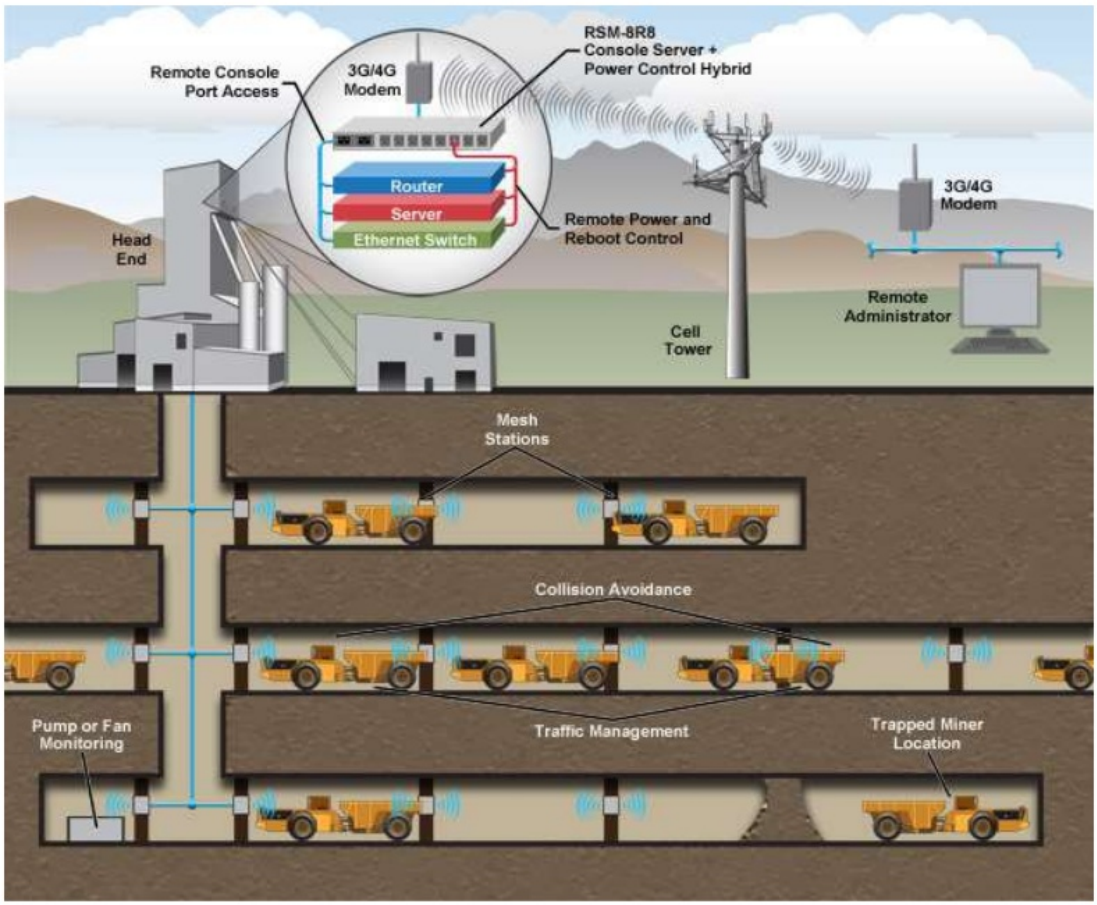


5.4. [b] Mine-Wide Communication:-

Large attenuation of radio wave in hard concrete coal strata poses a problem in covering the large communication range. Labyrinth path and complex geological conditions of mines further put hindrance in wireless communication. Corners and bends in underground mine galleries presents the obstacles to the propagation of UHF radio waves. But if in an active antenna is placed near/at the turn of the path, the signal may be amplified to give better communication. Further, we cannot go for higher wattage of transceivers due to intrinsic safety limit in hazardous area (i.e. coal mine). In order to establish mine wide communication system keeping in view of all the above conditions, I propose leaky feeder cables as antenna as well as transmitting lines. A leaky feeder allows signals to leak out of or into itself at a controlled rate. If effectively behaves as a long antenna that can guide radio waves around corners and bends. The communication system is featured by very high frequency (VHF) frequency modulated (FM) high band operation in the 146-174 MHz with an acceptable radio frequency (RF) power output as required for an underground mine. The cable is characterized by excellent frequency response over the required spectrum to meet the specifications of mine industries. It may be fire resistant, water resistant, etc. according to the needs of the same. Line amplifiers are inserted after every 350 meters of the cable to automatically compensate for the RF loss or other additional loss in the cable. These amplifiers operate independently in both the forward and reverse directions. All equipment's connected to the cable are powered from the cable itself. The VHF transceivers with intrinsically safe within 2 watts with loop antenna and leaky feeder cable as transmitting media followed by repeater at regular intervals would be used for communication through galleries. Due to skin effect phenomena, the radio weaves emit (leak) in larger periphery through leaky feeder cables and with help of repeater, the attenuated waves can be further amplified. By placing repeaters at regular intervals, the entire mine area can be covered.

5.4.[c] TRAPPED MINER COMMUNICATION

In underground mines, sometimes due to fissured strata, the roof or sidewall of a gallery collapse, miners get trapped inside sealed area. Many miners get trapped beneath the big chunk of fallen roof. A communication link between the trapped miner and rescue team is essential to find out the actual location of trapped miner for rescue operation. Studies revealed that attenuation of low frequency is comparatively lower through coal block. The low frequency tone signal modulated over RF signal 457 KHz can be transmitted through large thickness of coal block.



5.4. [c][i] INTRINSICALLY SAFE VOIP PHONE HANDSET

(Approved by DGMS, approval no. 651 of 2013 manufactured by Mine Site Technologies Pty. Ltd, Australia)

[c][ii]I.S. MINEPHONE HANDSET SPECIFICATIONS

Mine Site Technologies' MinePhone handsets offer a simple and robust solution for Voice over Internet Protocol (VoIP) communications in mining environments. The handset allows users to make and receive VoIP phone calls from any area of the mine covered by the wireless network and includes mine specific functionality including Push To Talk (PTT), emergency alarms and a battery life designed to last an entire shift. The handset is IEEE 802.11b/g (Wi-Fi) compliant and uses Session Initiation Protocol (SIP) for both voice calls and text messaging. The units can be configured using the on screen menu system or via a web browser simplifying system deployment.

Handset Specifications:	• Wi-Fi 802.11b/g	**Voice Features**	• G.711 (A-Law & µ-Law 64kbps). • G.729A (8 kbps). • Acoustic echo cancellation. • Jitter buffer control (default 80ms, max 320ms).
Dimensions:	• 150mm x 75mm x 35mm		
Battery:	• 1100mAh		
Charge life:	• 3 hours talk time. • 72 hours standby time.		
Transmit power:	• +17dBm.		
Screen:	• 240 x 320 Colour TFT.		
Weight:	• 250g	**Telephony Features**	• Call forwarding. • Caller ID. • Call waiting. • Call mute. • Re-dial (Last 20 records). • Hot key dialling. • Text messaging (stores up to 100 messages). • Multiple ring tones. • Phone book (up to 200 records). • Power saving mode. • Speaker and microphone volume controls. • Vibrating alert and silent mode.
Network Protocols	• TCP/ UDP/ IP, IPV4, DNS ARP, Static IP DHCP. • Real Time Transfer Protocol (RTP). RFC 1889/ RTCP FC 1890 • Session Description Protocol (SDP) RFC 2327 • Session Announcement Protocol (SAP) • Session Initiation Protocol (SIP) RFC 3621, 3624 & 3515 V2. • Standards – Call control & text messaging (RFC 3261 & DPRFC 2321) • DTMF RFC 2833 • Software updates by TFTP.		
		Mine Specific Features	• 24 Push to talk (PTT) channels • Man Down Emergency over ride • External headset *(non I.S. version only)* • Asset locator (when used in conjunction with MST tracking system
		Certifications	**Certificate No.**
Wireless Security	• WEP (64/128 bit encryption) • WPA • WPA2	IEC - Exia MSHA - Exia	IECEx TSA 10.0023X 23-A100006-0

5.4.[d] PERSONAL EMERGENCY DEVICE SYSTEM

(Approved by DGMS, approval no. 629 of 2011manufactured by Mine Site Technologies Pty. Ltd, Australia)

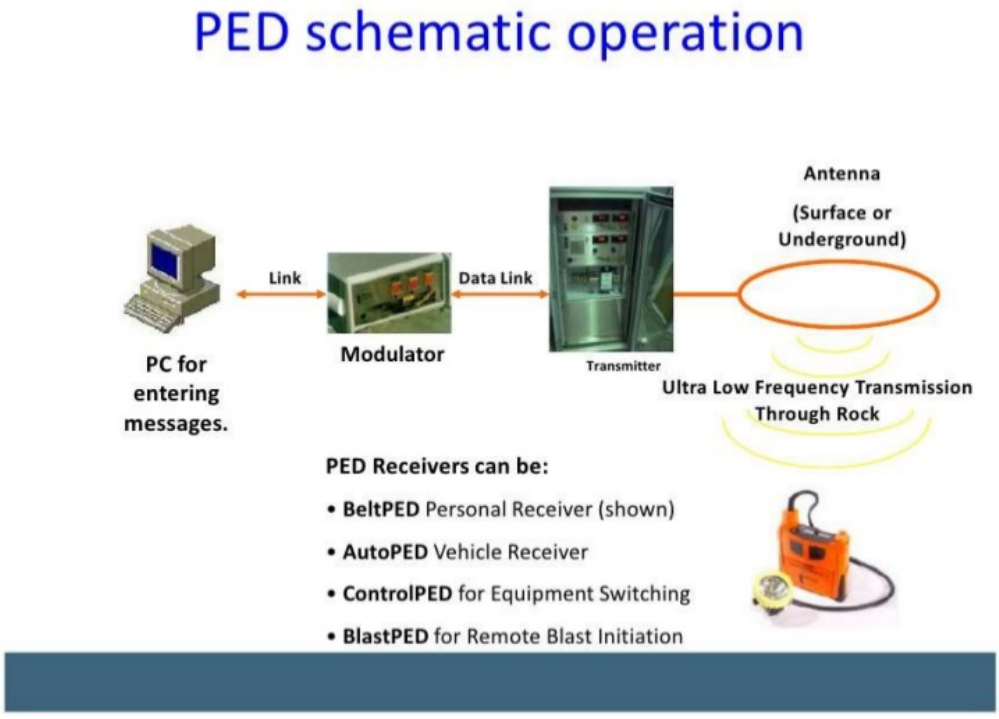
The personal emergency device (PED) communication system is one way TTE (inside the mine) system operating at frequency range of 1 KHz for digital text messaging. It is first demonstrated in United States in 1990. The first successful evacuation of miners attributed to PED technology occurred during the Willow Creek Mine fire in Helper. Utah, in November 25, 1998(Helper, 1998). It is a portable device which utilizes Ultra Low Frequency (ULF) range for mine wide text messaging that propagates through rock strata. It has been installed in over one hundred and fifty coal and metalliferous mines in Australia, USA, Canada, China and Sweden.

The PED system is an emergency warning system. PED stands for Personal Emergency Device. The use of ultra-low frequency (ULF) signals enables PED to transmit directly through rock strata, so wherever you are in a message can be sent to you. The mine wide signal coverage of PED also means it is very useful day to day communication system. Hence PED also stands for productivity Enhancement Device. Investment in a PED system is justified on significant cost savings and safety benefits.

PED receiver cap lamps

5.4.[d][i] PED OPERATIONS

PED uses ultra-low frequency (ULF) signals to send signals directly through rock, so called "through-the-earth" transmissions. The main difference between PED R and other so called through-the-earth systems is that PED R is proven and is operating in many mines, 24 hours a day, 7 days a week. PED R has been installed in over 150 mines since 1990. The system has been refined and enhanced over this time, but the basic working principles remain the same. The basic operation schematic is shown in the Figure below. The ULF transmission system transmits to a number of receiver types to allow a range of applications.



5.4. [d][ii] PERSONAL RECEIVER

Personal Receiver is integrated with a miner's cap lamp. This can be the ultra-light weight lithium ion battery pack, known as the Integrated Communications Cap Lamp (ICCL) , or receiver versions are available to retrofit to some existing Cap lamp batteries (such as Koehler- Wheat, Oldham, Northern Lights and MSA). On receipt of a message, the cap lamp flashes, a buzzer sounds, and the 32 character text message is illuminated on a liquid crystal display. The PED R receivers always indicate that they and the transmission system are operating.

5.4. [d][iii] TECHNICAL SPECIFICATION OF PED

TRANSMISSION SYSTEM

Transmission Headend

Frequency	ULF
Output Power	1.2kVA
Operating temp range	10°C - 40°C (50° F - 104°F)
Power requirements	110/240V AC
Includes	Earth leakage/ground fault detection and lockout
Dimensions	Housed in 19 inch rack cabinet (H=1200mm/48in; W=600mm/24in; D=600mm/24in)

Software

PEDCALL®	Windows based main system software Individual, groups & general broadcast Name search Custom text messages Priority Access Message log 15 second Emergency Message Facility Preprogrammed messages generated at specific times can be networked on mine's LAN
MINE MONITORING	Custom Interface to monitoring system for Automatic message generation, Monitors an unlimited number of inputs, Programmable messages to predefined personnel and devices

Smart External Modulator

Power	110/240 VAC
Input	RS-232 9 Pin to 9 Pin from PC Output 0-20mA to PED Headend
Features	Emergency message buttons (3)

RECEIVING DEVICES

Personal Receiver

Alert	Cap lamp 10 second flash, buzzer
Display	32 character liquid crystal dot matrix LED back light, Time display Message Storage (2), scroll facility
Voltage	Cap lamp battery nominal 4 or 7.5 volts
Power	40 mA
Weight	200 to 450 grams (1lb) depending on version.
Operating temperature	-20°C - 50°C (-4°F - 120°F)
Rating	IP67, Intrinsically Safe

AutoPED® Vehicle Mounted Receiver

Alert	Flashing light – 10 seconds Horn optional
Display	32 character liquid crystal dot matrix LED back light
Message storage	2 messages Scroll and delete functions
Power	10/28 VDC vehicle supply Automatic power shut down facility
Rating	IP65
Display dimensions	H=70mm W=220mm D=80mm H=3in W=9in H=3in
Antenna dimensions	L=170mm W=30mm D=30mm L=6.5in W=1.2in D=1.2in

Control PED® For Fixed Equipment

Power	110V AC 50 / 60Hz 24V AC 50 / 60Hz
Indicator LEDs	Power ON / OFF Transmission Status
Switching relays	110V AC / 5amp
Receiver dimensions	H=70mm W=220mm D=80mm H=3in W=9in D=3in
Antenna dimensions	L=170mm W=30mm D=30mm L=6.5in W=1.2in D=1.2in

BlastPED® Remote Blasting System

Capacity	Capable of firing 160 ohm series circuit
Security	Individually coded receivers System access only via floppy drive disk Key/Switch to Receiver Independent supervisory circuit Sequenced command string
Indicator LEDs	Battery Status, Receiver ready, Arm, Blasted
Rating	IP66
Dimensions	H=480mm Diam=140mm H=19in Diam=5.5in

6. FIELD TRIALS

- The field trials were performed in 9th and 12th pits of the Bagdiggi Colliery (depth around 200 m from ground to surface), BCCL, Nandira mine (inclined mine), Talcher area, MCL and Chinakuri Mine (depth around 612m from ground to surface), ECL with, UHF transceivers, VHF transceivers, trapped miner locators and induction theory based communication system.
- The VHF and UHF transceivers were tried in straight galleries of the underground mine for line-of-sight communication purpose. It was observed that the range of UHF transceivers was about 300 m (width around 4 m) and the range of VHF transceivers is about 75 m.

  The trapped miner locator had a range of about 30 m in a straight gallery and was able to penetrate a 3-4 m thick wall.
- The induction theory based communication system was tried in moving cage and was observed that the communications were established properly with the person available at the surface and person available in the moving cage.
- The cage communication was also done with the UHF transceivers. The communication was made from surface to moving cage and then to pit bottom. It was also observed that the communication extended to a further 10 m from pit bottom.
- The other experiment was performed for line-of-sight communication in the underground gallery using the same induction theory based communication system. It was observed that the communication could be made to the point up to which the continuous induction is possible.

7. CONCLUSION

Traditional mine communication system (Normal Telephone) can be effectively replaced by the personal emergency device (PED) and VOIP Phone Handset for better safety to the miner working in underground mines proposed in the paper. This paper gives detailed system of wireless communication which is used in several mines along the world including USA, CANADA, SOUTH AFRICA, AUSTRALIA, and in many more. This paper specifies in detail the systems of intrinsically safe wireless communication, approved by DGMS which includes PED cap lamp receivers and VOIP Phone Handset for safety and security of underground mines. This system is reliable, faithful, uninterrupted, economical and user friendly. A larger area and more depth inside hazardous underground mines are now can be covered and potential accidents can be controlled effectively.

Now proper monitoring and conversation is possible between the workers and the ground staff which can help to take appropriate actions more rapidly and smartly. The system also can be easily extended and it will improve scalability of underground environment and extend accurate position of miners.

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The tragic events at the Darby, Alma, Sago and Brookwood No. 5 Coal mines have highlighted the need for reliable communications between miners working inside a mine and those outside, Writers Institute for Occupational Safety and Health (NIOSP) Pittsburgh Research Laboratory's William H Schiffbauer and Jurgen F Brune.

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Thank You!