SLOPE MONITORING BY TDR – A LOW COST SYSTEM

[1]Prof.S.jaynathu,[2]Guntha Karthik, [3] G.Manekar,

Professor,Phd.Scholar, Mining Engg Dept.,NIT Rourkela,Odisha

[3]Dy.G M (Mines), ,MOIL Limited.

sjayanthu@yahoo.com, gunthakarthik424@gmail.com, g.manekar@rediffmail.com

Abstract

Slope stability is one of the leading problems faced by opencast mines. The conventional geotechnical sensors are generally monitored by technicians in the field and the available wireless monitoring systems like SSR, LiDAR are more expensive. The purpose of this paper is to introduce the effective real-time slope monitoring systems and the application TDR along wireless sensor networks. The wireless Data Transmission System using advanced antennas at respective slope instruments in underground or opencast mines can be used collect data without any physical connections. Wireless sensor networks (WSNs) are well suited to monitor the movement and it consist of sensor nodes which measure physical quantities and transmit the preprocessed measurement results to a base station wirelessly. Developments in information and communications technology (ICT) support the collection, connection and analysis of data through sensing and monitoring of slopes in mines. As a part of Ministry of Mines sponsored project, the above system is proposed to be implemented ***for the first time in India*** *in Dongri Buzurg mine of MOIL-Limited.*

INTRODUCTION

Sensors are parts of all machines that gather data and have an integral role in subsequent processing and transmission of data. Remote monitoring of slope movement using electronic instrumentation can be an effective approach for many unstable or potentially unstable slopes. Many options are available for monitoring unstable and potentially unstable slopes.Conventional systems like total station monitoring, extensometer, piezometer and inclinometers etc., are difficult for installation and separate man power required for collection of readings from instruments in mines. A TDR technology based on XBeecommunication is proposed. Wireless communication is the burning need today for the fast, accurate, flexible safety and production process in mines.Communication is the main key factor for any industry today to monitor different parameters and take necessary actions accordingly to avoid any types of hazards. To avoid loss of material and damaging of human health, protection system as well as faithful communication system is necessary in mines.

TIME DOMAIN REFLECTOMETRY

The basic principle of TDR is similar to that of radar. In TDR, a cable tester sends a voltage pulse waveform down a cable grouted in a borehole. If the pulse encounters a change in the characteristic impedance of the cable, it is reflected. This can be caused by a crimp, a kink, the presence of water, or a break in the cable. The cable tester compares the returned pulse with the emitted pulse, and determines the reflection coefficient of the cable at that point. Electrical energy travels at the speed of light in a vacuum, but travels somewhat slower in a cable. This is called the velocity of propagation. The TDR generates a very short rise time electromagnetic pulse that is applied to a coaxial system which includes a TDR probe for rock mass deformation and samples and digitizes the resulting reflection waveform for analysis or storage. The elapsed travel time and pulse reflection amplitude contain information used by the onboard processor to quickly and accurately determine rock mass deformation for slope stability measurement or user-specific, time-domain measurement (Fig.1).A 250-point waveform should be collected and analyzed in approximately two seconds. Each waveform should have approximate up to 2,048 data points for monitoring long cable lengths used in rock mass deformation or slope stability.TDR for determining ground movement requires reading the cable signature at regular time intervals. Ground movement, such as slip along a failure zone, will deform the cable and result in a change in cable impedance and a reflection of energy.This change can be used to determine the location of shear movement.

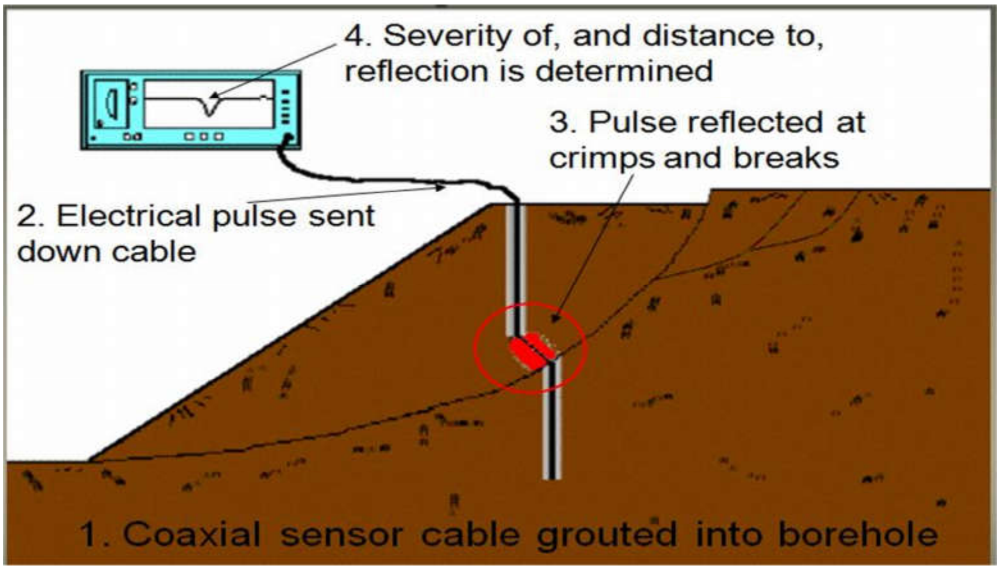

Fig.1. Basic Principle of TDR (Kane, William F.,and Timothy J. Beck,2000**)**

The change in impedance with time corresponds qualitatively to the rate of ground movement.TDR cable readings showed the development of a spike in the cable at a depth of 48-ft indicating movement in a typical TDR system is shown in Fig 2. It is also proposed to install TDR system as (Fig 3) to monitor the zone of movement along the slopes through WSN.

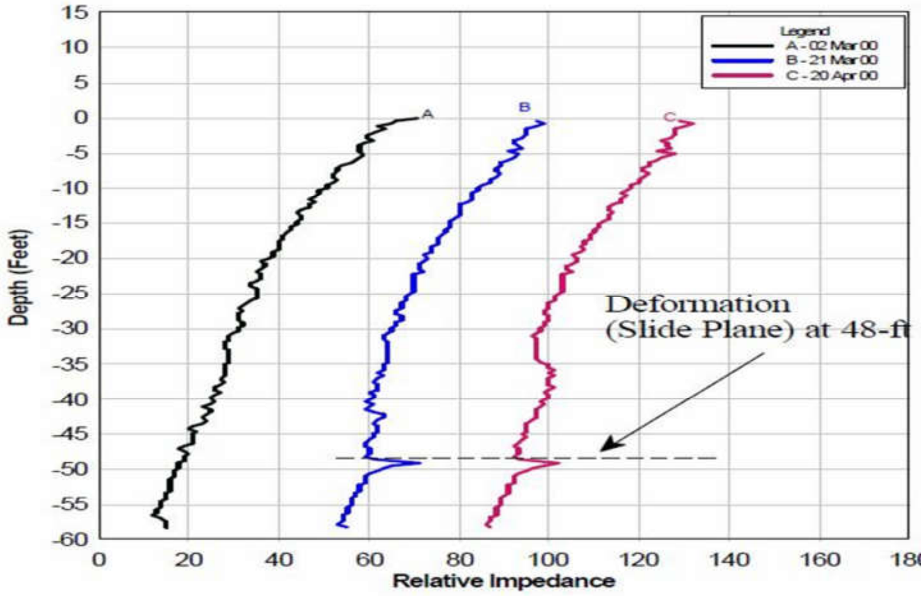

Fig.2.TDR cable signatures showing development of a shear zone

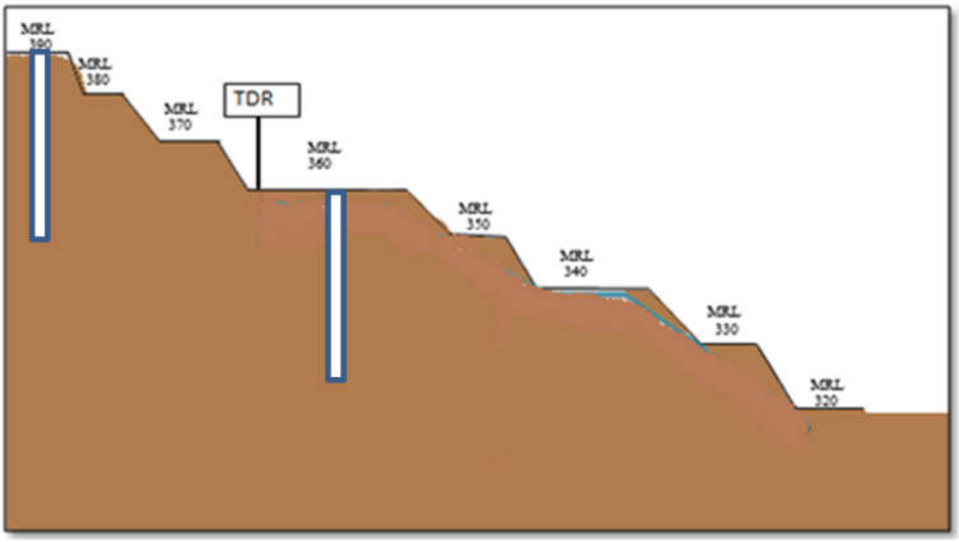

Fig.3. The Proposed Cross sectional view for installation of cables of TDR in DB Mine of MOIL (S Jayanthu, 2015)

DESIGN OF HARDWARE SYSTEM

An advanced wireless system for mines is proposed to update the slope movements in opencast mines to the base station immediately and updating it to the web server and sending alert message to the authorized person (S Jayanthu, 2014). Block diagram of wireless system is shown in Fig.4. Here we have opencast section and the base station section. In the underground section first step is to connect all the 8 cables in the Multiplexer (MUX). From the MUX 1 Output is connected to the TDR sensor to know the updates that the cables are in correct positions and working properly. Next is to initialize the TDR sensors in order to sense the corresponding sensor levels in the places. These sensed Analog values are converted in to digital values by using ADC and then there is a connection between Micro-controller (MC) and ADC and the same digital values are shown by LCD

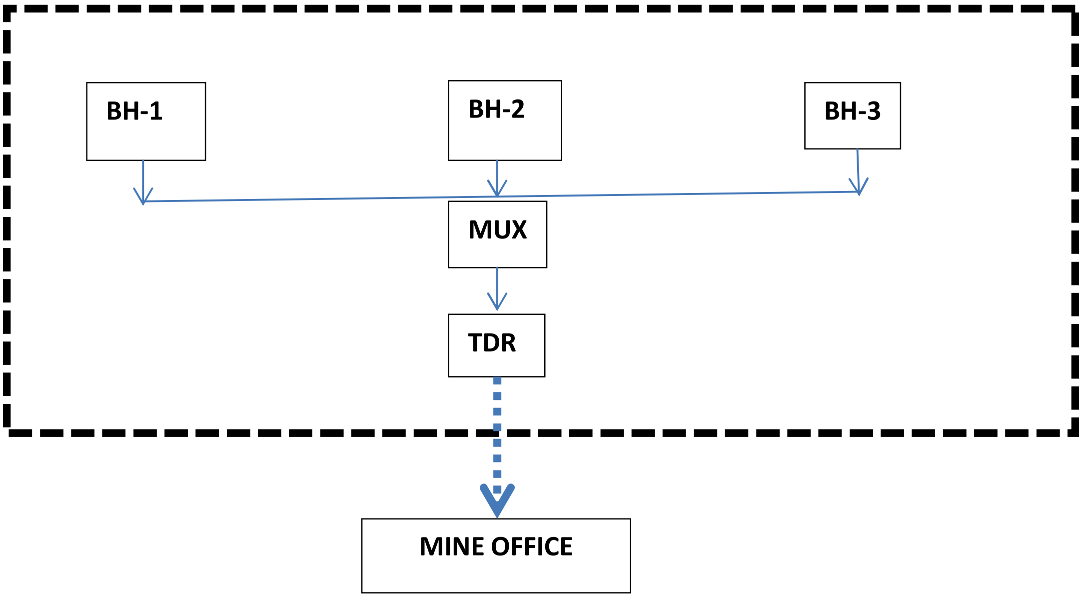

Fig. 4.Block diagram of proposed system in DB Mine of MOIL

The information is sent through RS-232 to XBee of the base station directly. If the sensor values exceed the threshold values then the alarm in the mines gets ON to alert the miners who work in the mine site regarding the emergency.

XBee

ZIGBEE is a new wireless technology guided by the IEEE 802.15.4 Personal Area Networks standard. It is primarily designed for the wide ranging automation applications and to replace the existing non-standard technologies. It currently operates in the 868MHz band at a data rate of 20Kbps in Europe, 914MHz band at 40Kbps in the USA, and the 2.4GHz ISM bands Worldwide at a maximum data-rate of 250Kbps. The ZIGBEE specification is a combination of Home RF and the 802.15.4 specification(Fig.5). The specification operates in the 2.4GHz (ISM) radio band - the same band as 802.11b standard, Bluetooth, microwaves and some other devices. It is capable of connecting 255 devices per network. The specification supports data transmission rates of up to 250 Kbps at a range of up to 30 meters. ZIGBEE's technology is slower than 802.11b (11 Mbps) and Bluetooth (1 Mbps) but it consumes significantly less power. 802.15.4 (ZIGBEE) is a new standard uniquely designed for low rate wireless personal area networks. It targets low data rate, low power consumption and low cost wireless networking, and its goal is to provide a physical-layer and MAC-layer standard for such networks. Probably the main feature of ZIGBEE is its limited power requirement. ZIGBEE is better for devices where the battery is rarely replaced, as it is designed to optimize slave power requirements, and battery life can be up to 2 years with normal batteries. Bluetooth is a cable replacement for items like phones, laptop computers and headsets. Bluetooth devices expect regular charging and use a power model like a mobile phone.

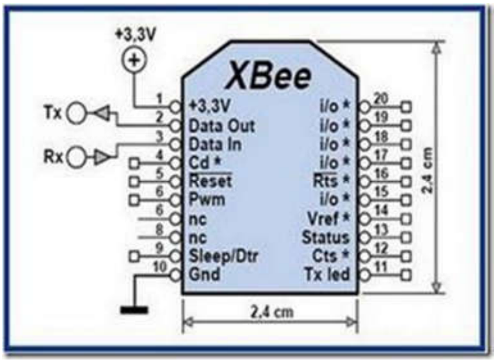

Fig.5. Pin Diagram of XBee (D. Egan, 2005)

Pin diagram of X-Bee Transceiver Zigbee modules feature a UART interface, which allows any microcontroller or microprocessor to immediately use the services of the Zigbee protocol. All a Zigbee hardware designer has to do in this case is ensure that the host's serial port logic levels are compatible with the XBee's 2.8- to 3.4-V logic levels. The logic level conversion can be performed using either a standard RS-232 IC or logic level translators such as the 74LVTH125 when the host is directly connected to the XBee UART.

Design Notes

Minimum connections required are VCC, GND, DOUT& DIN. Minimum connections for updating firmware are VCC, GND, DIN, DOUT, RTS and DTR. Signal Direction is specified with respect to the module including a 50kPull-up resistor attached to RESET .Several of the input pull-ups can be configured using the PR command. Unused pins should be left disconnected System Data Flow Diagram.

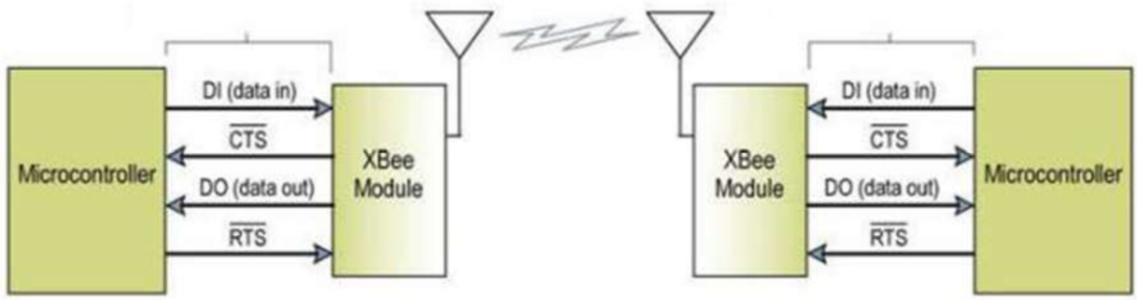

Fig.6.Data Flow Diagram of the X-Bee RF (H. K. Chan, 2010)**.**

Modules interface to a host device through a logic-level asynchronous Serial port. Through its serial port, the module can communicate with any logic and voltage Compatible UART; or through a level translator to any serial device. Data is presented to the X-Bee module through its DIN pin, and it must be in the asynchronous serial format, which consists of a start bit, 8 data bits, and a stop bit. Because the input data goes directly into the input of a UART within the X-Bee module, no bit inversions are necessary within the asynchronous serial data stream. All of the required timing and parity checking is automatically taken care of by the XBee's UART. Just in case you are producing data faster than the X-Bee can process and transmit it, both X-Bee modules incorporate a clear-to-send (CTS) function to throttle the data being presented to the X-Bee module's DIN pin. You can eliminate the need for the CTS signal by sending small data packets at slower data rates. If the microcontroller wants to send data to transceiver, it will send RTS (Request to Send) signal. If the transceiver is idle it sends CTS (Clear to Send) signal (E. K. Stanek, 1988).

The RTS and CTS signals are active low. When microcontroller receives CTS command it will send data to the transceiver through DIN pin. The transceiver will send the data to microcontroller through DOUT pin. The communication between transceiver and the microcontroller at the transmitter and receiver is similar. The communication between transmitter and receiver is through RF communication.

Multiplexing

It possesses dozens of multi-parameter sensors on one fibre optic cable. It has fewer instrumentation channels. It integrates different measure and on the same system. It requires lesser connections. It has reduced penetrations and also reduced cost.It is more reliable.

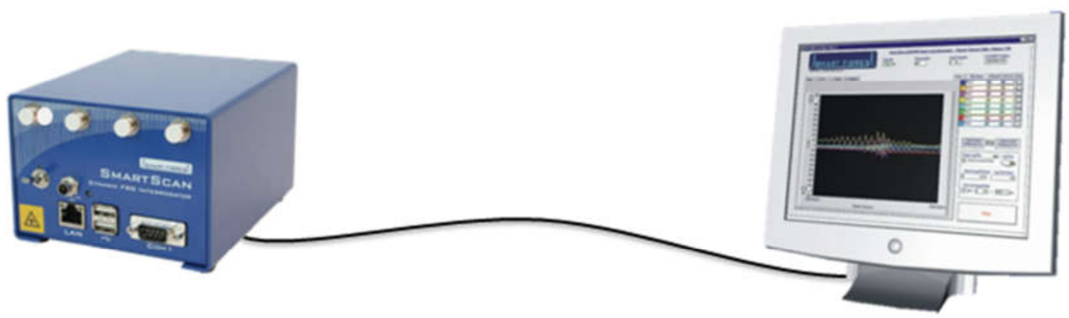

Fig .7. Interrogator system

CONCLUSIONS

An overview of TDR with wireless monitoring techniquesindicated that monitoring slope movements remotely with TDR techniques is a feasible alternative to more labor intensive methods like using survey monuments or inclinometers.The above system with TDR isproposed to be recommended for implementation in Dongri Buzurg mine of MOIL-India. The Ministry of Mines, Government of India sponsored the above project recently with necessary funds for procurement of components of the TDR system and arrangements of drilling and mounting for field implementation will be provided by MOIL .

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