On the safety wavelength

Christian Fimpler and Herbert Nüllmann, Eaton, Germany, detail wireless data and voice communication as important safety factors for shaft conveyor systems.

Modern shaft conveyor systems use radio systems for data transmission and voice communication to and from the conveyor. These systems have to fulfill the operational, climatic and safety-relevant aspects and requirements of deep mining.

Featuring explosion protection mode Ex ib I (intrinsically safe systems), the MR90 shaft radio system from Funke & Huster Bergbautechnik GmbH in Mülheim an der Ruhr, Germany, not only meets the explosion protection requirements, but also the high technical and functional requirements of the TAS Directive (Technical Requirements for Shaft and Inclined Conveyor Systems, German Regulations for Mines) in their entirety.

In addition to transmitting and receiving data, the system includes an integrated bi-directional voice connection, enabling communication with the conveyor operator.

Thanks to its modular design and operating mode, this basic concept can be extended to a size of 64 digital inputs/outputs and up to 16 analogue input values. This enables collection and transmission of a large package of safety-relevant information from the conveyor, such as emergency stop, gate and door monitoring, hoist blocked switch and slack rope monitoring. Moreover, it is possible to transmit commands from the conveyor directly to the automatic drive system, and to send feedback to the conveyor.

Basic structure of the mine radio system

The MR90 mine radio system has two stations enabling bi-directional communication using individual omni-directional antennae. One of the two radio stations is located on the conveyor (cage station: Figure 2), while the other one is mounted close to the drive system and/or control room (fixed station: Figure 1). In both housings, there are two rear-frequency transmitters and receivers, one rear-frequency front-end module connected to the antenna, one low-frequency interface for connection of a microphone and loudspeaker, as well as one data radio modem with corresponding analogue and binary input and output modules. By means of the location identification codes listed in the plant-specific circuit documents, the individual parts of the system can be allocated clearly.

An ANTM03/3 antenna, developed by Funke & Huster Bergbautechnik, is used as shortened λ/4 antenna. The outstanding feature of this is its antenna gain optimised for both transmission bands (27/35 MHz). A perfect level is thereby ensured for transmitting and receiving direction.

Depending on the local conditions and the received signal level values established in several test runs, the antennae are mounted on suitable supports on the conveyor (cage antenna: Figure 3) and in the shaft (shaft antenna: Figure 4).

The corresponding mounting devices are designed in a way to ensure quick and easy replacement of the antennae.

Figure 1. Cubicle MR90 system (fixed station).

Basic operating mode and monitoring mechanisms

Electromagnetic waves in the shaft are transmitted by antennae: one antenna is connected to the fixed station and installed below the pithead and the second is connected to the conveyor station (mobile station/cage station) in a place that enables perfect and uniform transmission quality.

The MR90 mine radio system is a duplex system, which uses the 27 MHz band for transmission from conveyor to fixed station (up-link) and the 35 MHz band for down-link transmission. These frequency ranges were selected and defined for the transmission bands to improve interference immunity, for example, regarding electromagnetic interferences generated by the frequency converters of the hoisting drives.

One high-frequency carrier is used for transmission of voice from the conveyor to the fixed station and back. The other high-frequency carrier is used for bi-directional (duplex) transmission of data between the conveyor station and the fixed station.

In order to avoid ambiguity of bi-directional data transmission between the fixed station and the conveyor station, achieve a fixed coupling between the partner stations within a conveyor system and ensure separation from other radio systems operated in the same shaft or adjacent shafts; the main transmission parameters (station address, telegram length, addressing and arrangement of I/O modules) are adjusted to have only one defined point-to-point coupling during operation, i.e. one master station is allocated to one secondary station.

Conditioning (serial-parallel conversion) of binary and analogue signals is effected by the MOD02 data radio modem. The binary data stream is frequency-modulated and/or -demodulated according to the FFSK procedure, as well as transmitted and received via the 27 and 35 MHz band. The corresponding transmitters and receivers operate in a frequency range of 26.5 – 27.5 MHz and/or 34.5 – 35.5 MHz.

The input circuits of the input modules used are monitored for short circuit or break of conductor to prevent errors in feed lines from causing incorrect information. Errors are visualised using a diagnostic unit and transmitted to the respective remote station as well.

The MOD02 data radio modem, featuring parameter setting (firmware), is designed for multi-task operation with up to five tasks. If monitoring functions respond and/or alarm messages occur, rapidly responding change of task levels with short cycle times is effected to avoid accumulation of errors and to give diagnostic messages. Data transmission from the fixed station to a master computer or PLC system is effected by serial data transmission according to Specification Mining Sheet BB22444 or Coupling Procedure RK512.

Transmission of data using digital or analogue input and output modules, operating in parallel, can be effected alternatively or additionally.

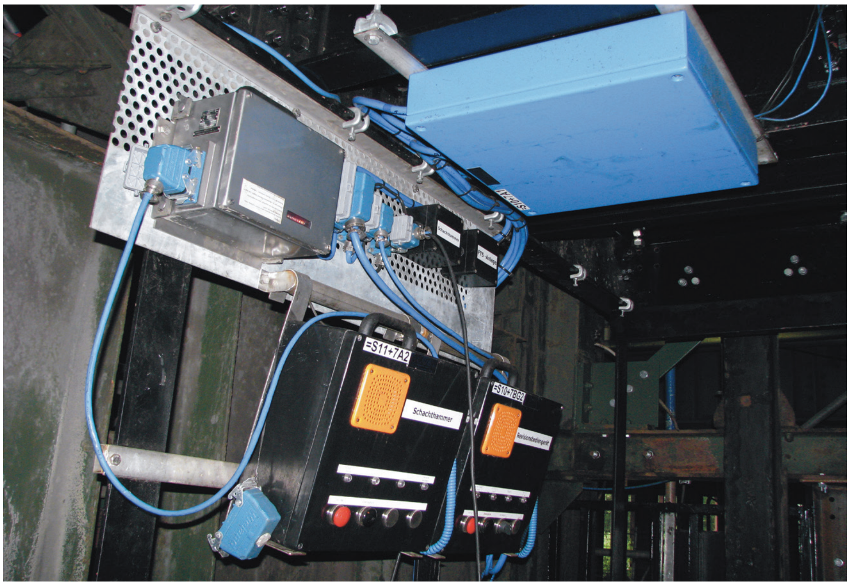

Figure 2. Cubicle MR90 system (cage station).

Monitoring of radio data transmission

The MOD02 data radio modem used as the master (conveyor station) transmits data telegrams periodically. Depending on the number of user data bytes to be transferred, the cycle time is about 100 – 200 msec. If the secondary station receives a valid telegram from the master allocated to it, the secondary station itself starts periodical transmission of data telegrams to the master.

If for a period of 900 msec. no telegrams or incorrect telegrams are received, only an error in radio transmission is reported to the process. The outputs of the output modules are reset, the error is shown on a diagnostic unit and a corresponding output is connected in parallel.

The error signal is deleted/cancelled when the next telegram is received without any errors.

The hardware used and the computer functions are monitored by secondary (software) tests with checks of the permanent and temporary memory (ROM/RAM); in particular, data transmission is protected against faulty output by toggle bit transmission and detection of received errors by verification of telegram length and contents (e.g. parity or framing error detection), block check mechanisms (even parity, CRC check), as well as sending and verification of two start and end of telegram identifiers. The data transmission safety equals a hamming distance of at least D = 4 (three bit errors in a telegram frame can be detected).

Operating the local I/O modules on the MOD02 modem requires the connected module types to be prescribed and parameterised. The MOD02 detects whether the connected I/O module actually complies with the parameterised type and address – for example, if the I/O module connector is removed or defective, or if an incorrect address is set. Additionally, if the electronic system of the I/O module is defective, a module error (local I/O error) is detected. It is possible to show the error messages on a connected diagnostic module.

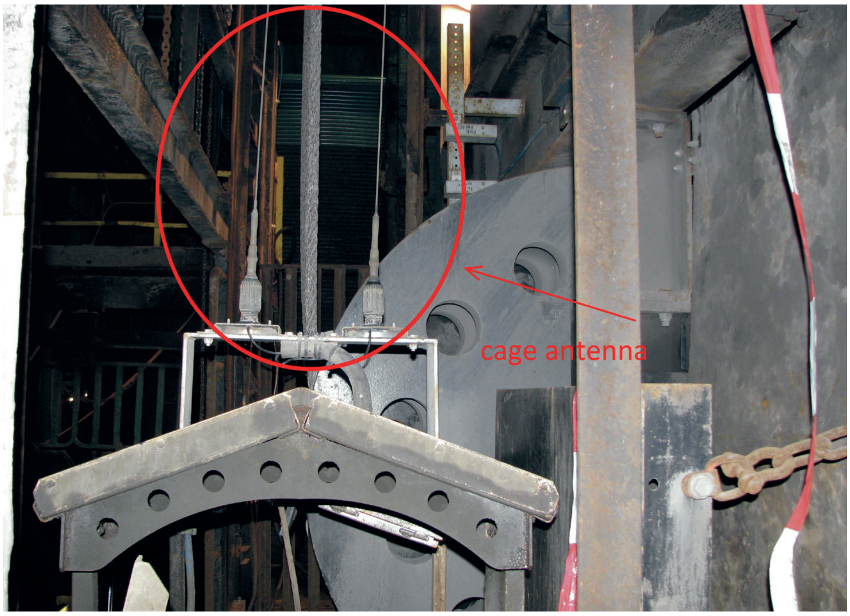

Figure 3. Cage antenna.

Figure 4. Shaft antenna.

Summary

Enhancing safety is a central theme of the design and the MR90 shaft radio system has been proven to be a reliable instrument in shaft conveyance, which, on the one hand, goes back to the analogue, frequency-modulated radio transmission technology in the selected frequency range and on the other hand, to the extensive protection and error monitoring of the safety-relevant, bi-directional, serial telegram transmission.

In order to avoid mutual interference, technical as well as organisational aspects are of utmost importance too. This is why the MR90 shaft radio system is designed in such a way to exclude external or mutual interference by numerous adjustable allocation and coding options that protect remote data transmission.

Finally, it should be mentioned that due to continuous improvement in the system development, operational safety and availability is enhanced. Modern modem chips are able to repair parts of a defective radio telegram on the receiving side and to thereby ensure further improved transmission safety/rate. Repeated telegrams are avoided.

Numerous interfaces enable simple connection to a variety of shaft conveyor systems and radio system diagnostics. Due to further optimisation of all high-frequency components, the system is less susceptible to outside interference.

This is very important in today's age of mobile connectivity of manifold devices and components, since many different radio services and electromagnetic interference sources affect the system.