Conceptual model of radio complex to ensure the safety of underground production mining

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Abstract. The paper presents the basic structure of multifunctional security systems for underground mining. It proposes a conceptual model of a telecommunication system, otherwise referred to as a radio complex, for monitoring the environment of a mine, positioning and ensuring the safety of miners. The authors describe a method for timely and reliable data transmission based on mobile robots to prevent emergencies during underground production mining.

1. Introduction
Mining operations are carried out in hazardous geological conditions associated with the risk of all kinds of accidents.

In this regard, the “Security Rules for Coal Mines” spells out the need for multifunctional security systems. These systems should forecast various types of geodynamic and anthropogenic hazards through geophysical and seismic monitoring of a rock mass in order to prevent sudden emissions and rockbursts [1].

The paper deals with a conceptual model of a mine telecommunication system for ensuring the safety of miners during underground production mining and can be considered as the scientific basis for a patent [2]. The paper is primarily geared to identify whether it is reasonable to apply new concepts to the development of mine telecommunication systems, in particular for the prevention of human error, a contributing causes of risk events, through full or partial automation.

2. Multifunctional security system (MSS)
A modern MSS for coal mines is a structural complex of subsystems that perform various functions aimed at monitoring the background situation in a mine in order to ensure the safety of mining operations. All subsystems comprise an integrated MSS [3] presented in Fig. 1.
MSSs ensure stable and rhythmic mining operations by preventing emergency situations. They provide timely and reliable information about possible dangerous situations and phenomena, through the actions aimed at emergency control and protection [4].

Unfortunately, despite a large variety of existing modern technologies and technical solutions, MSSs have a number of disadvantages related to radio communications. Therefore, advanced underground radio communications able to ensure safety in mining is a vital scientific and technical challenge [4].

The main drawback of MSSs involves unstable and untimely transmission of telemetry data due to insufficient coordination of subsystems, plentiful infrastructure in mines and, finally, inability of radio waves to pass through the ground for a required distance.

It is proposed to solve this problem by developing a radio complex based on autonomous mobile robotic platforms and smart information technologies.

3. Conceptual model of a mine telecommunication system

Today, there are many technical solutions in the field of robotics [5] and smart information technologies [6]. Once applied to MSSs, mobile robots and smart information technologies can solve a great deal of problems, primary of which are monitoring the environment of a mine as well as stable and efficient data transfer.

The proposed conceptual model of a telecommunication system for underground mining is presented in Fig. 2 by structural (a) and functional (b) diagrams.

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**Figure 1.** Structural diagram of a multifunctional security system (MSS)

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Figure 2. The mine telecommunications system: a – structural diagram; b – functional diagram

1 – Command station control unit;
2 – Data cable;
3 – Underground automated control station;
4 – Individual device of a miner;
5 – Mobile robotic platform;
6 – Controller;
7 – Wireless router;
8 – Video camera;
9 – Environmental sensor units.

The telecommunication system [2] is composed of a command station control unit, an underground automated control station that comprises a mobile robotic platform and individual devices of miners. Mobile robots and individual devices are integrated into a single wireless network. Each miner and each robot are equipped with individual radio devices similar in their characteristics and thus performing common functions – monitoring the environment, supporting positioning systems, transmitting data over a local network, amplifying and relaying transmitted signals. Each radio device contains a controller with a wireless router, a transceiver, environmental sensor units and a digital video camera. Telemetry data is transmitted to the underground (automated) and command (central) control units in real time. The number of mobile robots depends on the structure and length of the underground mine.

During operations miners move in different directions, and that deteriorates radio communication between them or makes it disappear at all. In this regard, radio signal transmission requires repeaters. Unlike analogs, in this telecommunication system they are mounted on mobile robots. These mobile robots are able to autonomously (without human intervention) move, subject to the feasibility of their location, and create access points for a self-organizing wireless sensor network using evolutionary modeling and optimization algorithms and bionic combinatorial optimization algorithms [7, 8].

In addition, mobile robots, with an appropriate technical solution applied, are able to perform the function of monitoring the environment of a mine, thereby warning of potential emergency situations.

4. Conclusion
Thus, the conceptual model of a telecommunication system for underground mining is a radio complex that can significantly reduce the risk of accidents in mines.

The proposed method for radio data transmission combined with existing technologies needs a multifunctional system to ensure the safety of miners during underground production mining.

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