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Research of Initiative Personnel Orientation and Rescue System in Mine based on Synchronous Signal Sensei Technology

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**Abstract**

According to shortcomings of short-distance signal recognition, low signal transmission reliability, high rate of leakage reading and single function that exist in current underground personnel orientation system, a new system based on Synchronous Signal Sensei with initiative RFID technology has been designed. The system's hardware and software is detailed designed including its working principle. The initiative communication process is realized by the SoC chip of nRF9E5. An emergency alarm circuit is added to the identification card. Based on the analysis of characteristics of underground wireless communication, a deep research was done to synchronous signal sensei technology and its realization process in order to reduce power consumption. Signal transmission mechanism is improved to return the correct confirm signal for once a time. The test results show that the communication distance between the card and the wireless location substation can reach 80m with 10 dBm of transmission power and 433.6MHz of communication frequency.

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**Keywords**: RFID; personnel orientation; nRF9E5; wireless RF communication; CSMA/CA

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1. Introduction

Grasping the miners’ dynamic distribution and working condition has great significance to safe rescue, disaster relief and accident qualitative [1]. At present, the mainstream of the miners tracking systems researched by domestic enterprises basically uses passive RFID technology [2,3]. Readers are set at some key places which can read passive electronic label (Tag) information to identify personnel location. There are some problems existing in this technology such as short communication distance (about 10m), poor anti-interference ability for using low frequency, the high rate of leakage reading and single function. According to above problems, this paper introduces a new personnel orientation and rescue system based on initiative RFID technology constructed by the SoC chip of nRF9E5.

2. System Composition and Work Principle

The structure of initiative RFID personnel orientation and rescue system is similar as current mainstream of passive RFID personnel orientation system [4]. It includes mobile identification card, position monitoring station, transmission interface, host (including display), system management software, server, printer, big screen, remote terminal, network interface, cable and junction box etc. Basic structure is shown in figure 1 below.

When mobile identification card gets in signal coverage area of position monitoring station, it will be aroused and sending staff number information actively. Position monitoring station in the usual is set in state of launching synchronous sensei signal, once received information form identification card, immediately turn to decoding, and then add station number. The final information is transferred to the ground staff positioning management system through bus cable. Management system can display the current staff position, track walk path and process alarm information. Mobile identification card also has emergency alarm function, used for various disaster for help. Personnel position is identified by the station, belongs to regional orientation.
3. The hardware design of system

3.1. Characteristics of Underground Wireless Communication

Underground wireless communications in a limited roadway space, the electromagnetic interference and multipath fading is much more serious than ground. Roadway cross-section size, rock properties, radiation of underground power equipment, tilt and turn roadway and other factors, all of them can impact the wireless communication reliability and distance. Fortunately, the frequency resource of underground communication is rich and it can be any band. According to research data [5], underground wireless communications cut-off frequency is 246MHz near 1GHz; it can better overcome the electromagnetic interference and has the best straight-line distance of effective communication. However, in this band, the attenuation is significantly at roadway turning. Its diffraction ability is less than 433MHz. Taking into account the location of monitoring sub-stations is usually set in the roadway forks, in this selection, 433MHz is chosen as the frequency of communication system.
3.2. Selection of the Core Component

Considering the low power consumption, anti-jamming and essential security features, and comprehensive comparison on the current mainstream short-range wireless communication technologies and chips, the wireless communication chip uses nRF9E5 which is a single chip RF transceiver and integrates the high-frequency antenna circuit and the single-ended whip antenna. nRF9E5 is the RF chip of system-level[6], it integrates nRF905 transceiver and 8051 Micro-controller, and works at 433/868/915MHz band. The time of switching between various bands is less than 650μs. Chip power consumption is very low, to -10 dBm launch power, operating current is only 11mA and receiving operating current is only 12.5mA, 2.5μA standby with wake up on timer or external pin. A variety of low-power mode (power-down mode and idle mode) is more convenient to make energy-saving design.

3.3. Hardware Design of Mobile Identification Card

As nRF9E5 is a chip of SoC, the mobile identification card mainly consists of nRF9E5, work lights, emergency alarm circuit, and power supply module and antenna circuit. The structure is shown in Figure 2.

![Fig. 2. Principle of mobile identification card](image-url)
8051MCU is the system control centre, through the SPI interface to control configuration and data communication of nRF90. When Identification card powered, the MCU first configures nRF905 registers, including the frequency, output power, communication address, data length, etc. Then it makes nRF905 into standby mode. When upon receipt of an external wake signal, the nRF905 will turn into the TX mode and launch code information. Emergency alarm circuit is set for underground emergency call with interrupt wake mode. Work lights are used to display identification card working condition.

3.4. Hardware Design of Position Monitoring Station

Position monitoring station mainly consists of the micro control unit (mainly nRF9E5), CAN interface module, working status indicator, the antenna circuit and power supply components. The structure is shown in Figure 3. When the embedded wireless chip nRF905 completes data reception, the 51MCU will receive data from the nRF905 and package it after decoding the data and adding sub-station address code, and sent it to the CAN interface module. The CAN module will complete communications with ground monitoring centre. CAN interface module uses CSM100 [7], it can directly implement the UART signals to the CAN signal conversion. Position monitoring station is powered by the AC-DC switching power. When power is cut off, it will through the power control module to start the backup DC power. Continuous supply time of DC power is not less than two hours.

Fig. 3. Principle of position monitoring station
4. Wireless communication design in synchronous wake-up process

4.1. Communication anti-jamming technology and energy saving design

Energy control of mobile identification card is the bottleneck to design of long-distance communication. When the identification card gets in identification area, in case of ensure can be identified, it should minimize the time in TX mode. So we use a Synchronous Signal Sensei technology to control the identification card’s working time. Identification card is dormant most of the time; it will wake-up by timer interrupt and turn into signal synchronization status. When received synchronous signal, it will send the code message to the station at regular intervals until received a confirmation command. The identification card will turn into standby mode after signal synchronization status. Synchronous wake-up interval is determined by the station density and identification region size.

In the course of a single wireless communication, according to the characteristics of the chip, using the carrier detection, address matching and CRC data checking mechanism to ensure the accuracy of data received. CSMA/CA of IEE802.11b is used as wireless anti-collision protocol which can effectively reduce the collision probability of multi-point communication [9]. Meanwhile, in the communication process, improving the traditional two-way handshake mechanism to once handshake that the card sends message to the station at regular intervals until received a confirmation command. This method can reduce sending times of the identification card.

4.2. Design of wireless communication protocol

According to requirements of energy-saving design, the system communication protocol format as follow [8].

[Preamble][Communication address][Identification card number][Flag code][CRC]

Preamble and CRC is automatically added by the nRF905. Communication address for address match, usually set 4 bytes, is set to 0xFFFF here. Identification card number is used to determine the source of personnel information and alarm information, with the length of 4 bytes, the capacity should meet the requirements (the provision of the capacity is not less than 8000). Flag code used to distinguish between location information and alarm information, with the length of 1 byte, "00H" is location information, "x1H" is alarm information, and different "x" indicates different alarm conditions.

4.3. Wireless communication process

(1) Software Design of Identification Card

Identification card after power on, first configures nRF905 to standby mode, turns off auto-answer, and disables the automatic reissued. It will turn into signal synchronization status when waked up by timer interrupt, then wait for external sync wake-up signal. It turns into the TX mode if received external signal, then writes address TX_ADDR and location data into nRF905 buffer from the SPI port. CE is set high and maintained at least 10μs, 130μs delay after data transmission. TX_DS is set high, the IRQ goes low, notices 51MCU that data transmission has completed. Then, nRF905 turns into standby mode. Emergency alarm subprogram will be wakened up by external button interrupt.

(2) Software Design of position monitoring station

Position monitoring station usually keeps in the state of sending synchronous signal. When the external feedback signal is received, it goes into RX mode, turns off auto-answer, and then delays 130μs to wait for data arriving. When the received data has been checked as correct, it will return a confirmed command to notice that the communication process is accomplished. Meanwhile, interrupt flag RX_DR is set high, IRQ low, notify the MCU to fetch the data. MCU will add the station address code and transmit it to the CAN interface module.
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(a) flow chart of the card  (b) flow chart of the station

Fig.4 Wireless communication flow chart
5. The experiment

Underground communication test has been done. The main transport laneway of Zhangxin coal mine of Jixi Mining Group was chosen as test place. The laneway was with shape of hemicycle, shoring form of anchor, and about 16 m² of cross section acreage. Position monitoring station transmitted the synchronization signal every 1s, transmission power was 10 dBm and the communication frequency was set at 433.6/868.0/915.2MHz respectively. The results based on analyse of the testing data showed as follows.

(1) At the condition of straight laneway, the three frequency above can respectively reach 80m,110m and 150m. It showed that the higher frequency, the further communication distance.
(2) At the condition of tortuous laneway, the attenuation of 868.0 MHz and 915.2MHz is more serious than 433.6MHz, and the diffraction ability of them is less than 433.6MHz. It showed that the larger turning angle the shorter communication distance.
(3) With the speed of 5m/s, the card can be identified by the station for 10 to 15 times.

According to the above results, we choose 433.6 MHz as this system’s communication frequency for its better diffraction ability.

6. Conclusions

The core of this personnel orientation and rescue system based on Synchronous Signal Sensei with initiative RFID technology is composed by nRF9E5 and its outside circuit. The underground communication distance can reach 80m and its main influence factors include laneway cross section, laneway gradient, laneway swerve angle, etc. In the future, identification card will be embedded in some portable instrument like miner's lamp in order to solve the continual power supply problem. Application of this system will help to enhance the management level of underground workers, and provide personal protection.

References


