International Journal of Trend in Research and Development, Volume 11(2), ISSN: 2394-9333
www.ijtrd.com

The Research on Mine Personnel Safety Positioning and Identification System

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Abstract: Coal mine accidents have occurred frequently in recent years, a safety positioning system applied to coal mine personnel was researched and designed. It combines with the characteristics of the coal mine wireless communications and is based on the RFID technology, sensor technology and computer network. The STC89C52 microcontroller produced by STC Company was chosen as the main chip of the reader and tag of the system because of its distinct advantages of high-speed, low power consumption and superior anti-interference. The nRF24L01 produced by NordicVLSIN Company of Norway was used as radio frequency transceiver chip. Based on the Microsoft Visual Basic and database Access, the software system of mine personnel safety positioning and identification system was established. The system researched and realized in this paper may achieve real-time location monitoring, safety monitoring and information management of the coal mine personnel. Once accidents happen, the managers on the ground may obtain the specific distribution of mine personnel timely and dynamically. The scientific evidence for the relief and rescue work can be provided by the system researched in the paper.

Keywords*: Mine Personnel Safety Positioning, Rfid Technology, Sensor Technology, Reader, Tag*

I. INTRODUCTION

In recent years, the safety and supervision of coal mine has been paid more and more attention. The monitoring systems have been widely used in coal mine safety production in large and medium-sized coal enterprises and the situation for safety production has improved considerably, but there is still a large gap compared with the developed countries [1-3].

Domestic coal mine accidents have occurred frequently in recent years and the efficiency of rescue after disaster is low, which reflects the present monitoring system being with defects [4, 5]. Once coal mine accidents happen, the managers on the ground are difficult to obtain the specific locations of underground personnel and the operation situation timely and dynamically. The reliable information can not be got, which causes rescue efforts slow and achieves a so-so and passable performance [6, 7]. The new mine personnel safety positioning system was researched and developed that could carry out the real-time tracking of personnel under the coal mine well. Even if coal mine accidents occur, the ground supervisor can locate the position distribution of personnel quickly through the computer management system. The research and realization of mine personnel safety positioning and identification system would provide scientific evidence for the relief and rescue work of the trapped coal miners, reduce casualties and economic losses to a certain extent and offer an inspiration for fast reconstruction work after disaster [8]. The system based on RFID technology could monitor the position distribution of coal mine personnel in real time, make the management mechanism of coal enterprise enhance and the work efficiency improve effectively and afford powerful technical support for coal mine safety management and emergency rescue and disaster relief.

II. SYSTEM COMPOSITION AND WORKING PRINCIPLE

The system based on radio frequency identification (RFID) technology is used to fix the position for coal mine underground personnel and can be divided into two parts of the ground part and underground part, as shown in Figure 1. The ground part is the transmission network including of the host, the interface converter, the remote server, the monitor and other auxiliary equipments. The underground part is composed of multiple readers and active tags. Tag information with all the information indexes of underground personnel inside is uploaded to the ground monitoring system through the data transmission interface and the communication optical cable. When the underground personnel with tags comes into the reader's reading scope, the tags send their information to the reader and, then, to the host computer through the serial communication. The data exchange is made with database created by the host computer management system. The position distribution of underground personnel is displayed with the main control computer timely and dynamically. The system can realize location, display, management and other functions for underground personnel in real time.

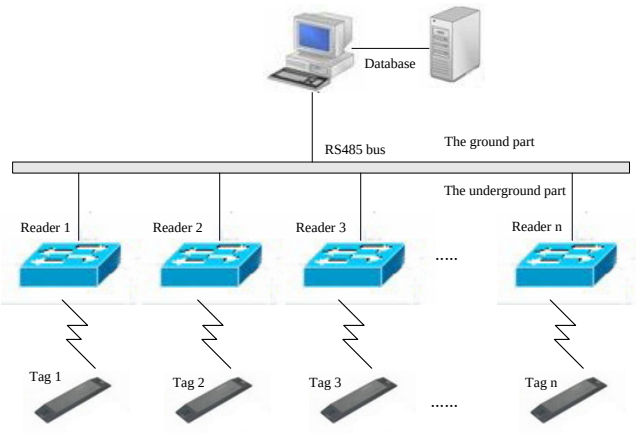

Fig. 1 The overall system architecture

The system software is mainly the special software for positioning management which exchanges background data with standard Access 2000 database to realize the real-time location of underground personnel. Each miner will be issued to an active tag whose ID number is unique before entering the mine. The ID numbers are corresponding with the detailed information of miners in the database, such as the name, date of birth, type of work, contact information and so on. The readers are installed in the tunnel. When the miners with tags go down and enter the interrogation range, the readers will read

the ID numbers and transfer them treated to the ground monitoring host with the bus RS485. The position information of the miners can be recorded through the connection between the host and the database of back-stage management. The dynamic position of the underground personnel can be monitored through the monitoring system.

III. DESIGN OF SYSTEM READER AND TAG

Radio frequency identification (RFID) technology is a kind of automatic identification technology originated in the 1990s [9]. It can carry out the data by the way of two-way communication with non-contact form and radio frequency to realize automatic identification and obtain relevant data of the objects recognized. The RFID system is usually consisted of three parts, the reader, electronic tag and data processing system [10], as shown in Figure 2.

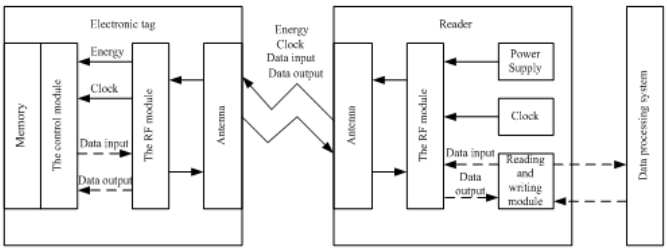

Fig. 2 The block diagram of RFID system

The electronic tags with relevant data of the objects recognized inside are usually installed on the targets to be identified. Each tag with a unique identification code transmits the information stored by antenna to the reader to read or write. The readers read or write the information stored in electronic tags via RFID technology and then the information can be managed and transmitted through data processing system. In the RFID system, the data operation processing system is used to dispose the data read by a reader to realize the communication transmission. The readers can connect the operating system through a standard interface to realize real time communication for data transmission.

A. Underground communication frequency selection

The attenuation decreases along with the increase of frequency in the bands of high frequency, ultrahigh frequency and microwave because of the influence of frequency on the underground wireless transmission. Take the influence of tunnel section of coal mine on wireless transmission into account, the ratio of the equivalent radius of tunnel to wavelength can be computed as follows:

$$\lambda = \frac{c}{f} \tag{1}$$

$$D = \frac{r}{\lambda} \tag{2}$$

Where r is the equivalent radius of tunnel section, in general, s_{tunnel}>6m^2, r>1.38m; D is the ratio of the equivalent radius of tunnel to wavelength. If D>10, the attenuation effect of the tunnel section to the electromagnetic wave is small, and the frequency f >2.18GHz. The frequency 2.4GHz is adopted to reduce the attenuation of electromagnetic wave in the tunnel and increase the transmission distance to the maximum extent.

At present, many scholars have done a lot of research and verification work about the transmission performance of wireless signal of 2.4GHz in mine tunnel and confirmed its linear transmission performance fine [11, 12]. With the increase of communication frequency, the electromagnetic interference of industrial equipment reduces constantly [13]. The frequency 2.4GHz can ensure the data quality of wireless transmission effectively with advantages of small electromagnetic interference, small attenuation and far transmission distance. At the same time, international treaties say the frequency 2.4GHz is free of charge and no application [14].

B. Hardware design of the reader

Considering the task demand and cost, the core chip STC89C52RCRC/RD+ with high running speed, low power consumption and strong anti interference ability was choosing in the system design. The instruction code of the core chip is compatible completely with the traditional 8051 single-chip microcomputer. The radio frequency chip nRF24L01 produced by Norway NordicVLSIN Company was selected. The nRF24L01 a new type of radio frequency transceiver is suitable for multi channel communication and its power consumption is very low.

The reader is mainly composed of radio frequency module, control module, sensor module, alarm module, power module, communication module and the antenna, as shown in Figure 3.

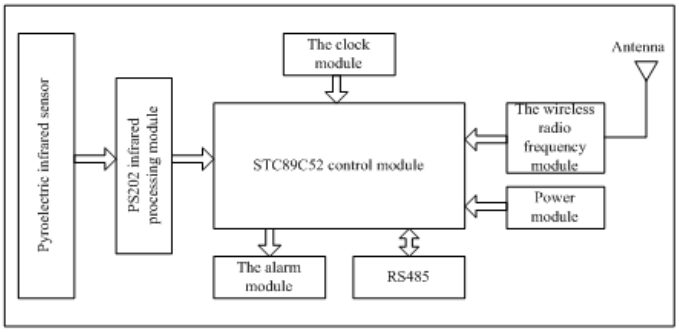

Fig. 3 Hardware circuit diagram of the reader

The radio frequency module with an antenna: mainly responsible for sending and receiving radio frequency signals and wireless transceiver nRF24L01 is adopted.

The main control module: the core of a reader. Adopting high performance micro controller STC89C52RC as the core, it can control the radio frequency module nRF24L01 to receive or transmit data and receive operation instructions from the control center. It can control the pyroelectric infrared sensor module to collect and process data and upload data by bus RS485. Once the abnormity status occurs the alarm module will start.

The pyroelectric infrared sensor module: responsible for converting the infrared signals received into digital signals which can be collected and processed further by the control processor.

The alarm module: alarm when the underground personnel enter the restricted area.

The power module: In general, the DC power supply is adopted in the reader. In the design, low power consumption should be considered primarily. The quality of the power decides the normal work of the reader is good or bad and affects the life cycle of the power. The input voltage is 5V and

the output modulated by a linear voltage stabilizing circuit is 3.3V which act as the normal working voltage of the whole module.

The communication module: responsible for transmitting the reader's information to control center through the transmission network.

Through chip selection and design of each module, the specific circuit of the reader can be shown in Fig. 4.

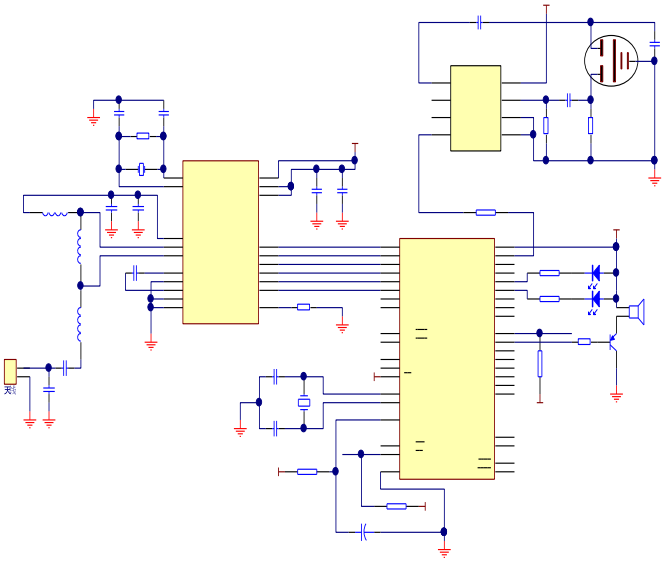

Fig. 4 The circuit diagram of the reader

C. Hardware design of the tag

The tag is usually installed in the miner's lamp or the safety cap or the waistband. Considering the small volume and the far communication distance, the active microwave tags were used in the system. The single-chip microcomputer STC89C52RC is adopted as the core control chip of the tag and nRF24L01 as the radio frequency chip.

The tag is primarily made up of main control module, radio frequency module, power module and peripheral serial interface, as shown in Figure 5.

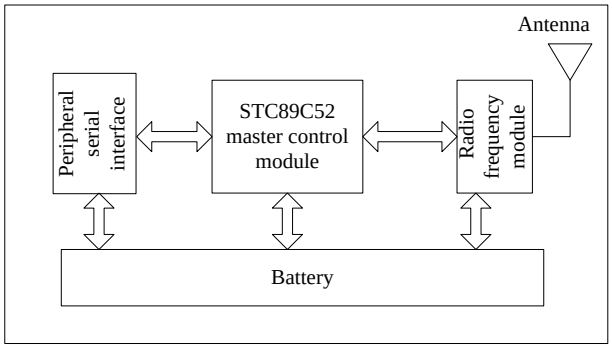

Fig. 5 The internal structure diagram of the tag

The main control module is responsible for receiving and transmitting data and controlling the tags to see if they work normally. The radio frequency module with an antenna is mainly in charge of sending and receiving radio frequency signals. The power module is responsible for supplying the normal working voltage to every parts of the tag and can control the opening and closing of the power at any time. The peripheral serial interface oversees expanding the chip for secondary development and utilization. The active tags were adopted in the system, so far data communication can be realized without increasing transmission power of the radio frequency module. The specific circuit is shown in figure 6.

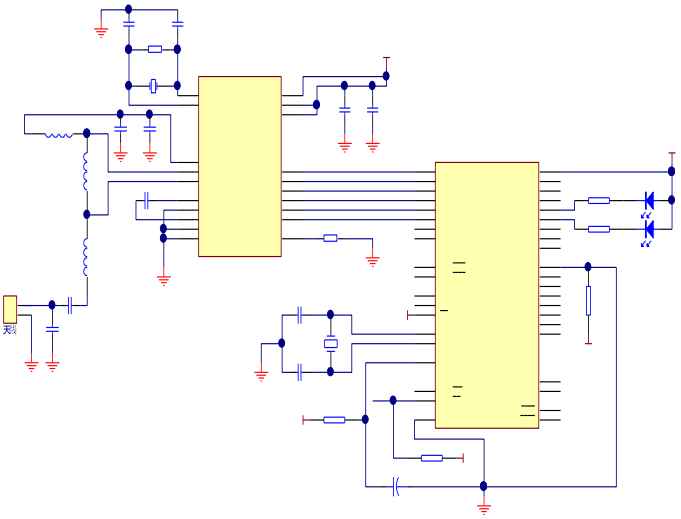

Fig. 6 The circuit diagram of the tag

D. Software design of the reader and tag

In general, the running time of program can be reduced through efficient algorithm in program design and thus reduce power consumption of the system. The tags send data to the reader automatically in the system. The part consuming large amounts of power of the tag is the radio frequency module. In order to reduce power consumption, the time to transmit data of the radio frequency module should try to reduce. As long as the radio frequency module sends out the data, the tag will enter a state of dormancy. In this mode, the tag need not keep sending status and the power consumption can be reduced greatly.

The readers play irreplaceable role in mine personnel safety positioning system and can complete underground personnel positioning and safety alarm function together with tags. After readers electrified, the system was initialized including of the system clock, sensor module, UART and radio frequency module. After initialization, readers gone into the receive mode and were ready to receive the radio signals of the tags entering the reading range. If no signal is received, it is indicated that no tag appears into the reading range of readers and, then readers will collect the infrared data with sensors. When the infrared data is collected indicates the underground personnel have crossed the restricted area, alarm signal will be sent out. If the radio signals are received, it is indicated that tags appear into the reading range of readers. The readers transmit the radio signals to the transmission network and then the ground control center via the serial interface.

The tags are the basis parts of mine personnel safety positioning system. The tags represent the only ID number of each underground personnel and realize wireless communication with the readers. The tags send the ID number and transmission power to the readers to identify automatically. After tags electrified, the system was initialized including of the main control module and radio frequency module. Tags gone into the receive mode after initialization. If the data is received, it is illustrated that other tags are sending data at the moment. The tag will delay for a period of time at random and the system enters a sleep state. After the system is awakened, the detection continues until no collision occurs. The tag sends

out the effective data packet formed with ID number and the transmission power through radio frequency module. If the transmission is successful, the tag gets into a sleep state of 2s and the radio frequency chip enters standby mode of I, otherwise the sleep time will be adjusted to 500ms and then the data is resent.

IV. SYSTEM SOFTWARE DESIGN

The system software is developed with Microsoft Visual Basic integrating data acquisition and information processing. The background adopts database of Microsoft Access and the operation platform is operating system of Microsoft Windows 7. The host computer management system composes of six modules such as the system settings, system maintenance, statistical analysis, attendance management, map maintenance and real-time positioning. The system settings mainly include the serial port settings and the Access data source settings. System maintenance is mainly responsible for the maintenance of initialization operation and related data of the whole system, including personnel information input, modify and delete and personnel information inquiry in accordance with the number, name and ID number. Statistical analysis includes real-time monitoring of the position of underground personnel. Attendance management is mainly charge of the daily attendance statistics and print. Map maintenance is mainly responsible for real-time display of the whole map. Real-time positioning is responsible for showing the position distribution of personnel underground on the monitoring host computer interface.

The system can realize real-time tracking of underground personnel. Even if coal mine accidents occur, the ground supervisor is able to locate the position distribution of personnel quickly through the computer management system. The research would provide scientific evidence for the relief and rescue work of the trapped coal miners, reduce casualties and economic losses to a certain extent.

CONCLUSION

A safety positioning system applied to coal mine personnel was researched and designed. It is based on the superior performance and low power of active tags and combines with the characteristics of coal mine wireless transmission. The single-chip microcomputers STC89C52 with distinct advantages of high-speed, low power consumption and superior anti-interference, produced by STC Company were chosen as the main control chip of the readers and tags of the system. The chip nRF24L01 from NordicVLSIN Company of Norway was used as radio frequency transceiver chip. Based on Microsoft Visual Basic and database Access, the software system of mine personnel safety positioning and identification system was established. The system researched and realized in this paper can achieve real-time location monitoring, safety monitoring and information management of the coal mine personnel. Once accidents happen, the managers on the ground can grasp the specific distribution timely and dynamically. The scientific evidence for the relief and rescue work can be provided by the system researched in the paper.

Acknowledgments

This work was supported by Key Research Project in Colleges and Universities of Henan Province (grant no. 23A460010).

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