Design of Railway Transportation Anti-theft Alarm System Based on Infrared Sensor

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Abstract: In view of the current problem of weak anti-theft capability of railway transportation, combined with the special requirements of railway transportation, compared with the common anti-theft technologies, the infrared sensor is selected as the anti-theft device. A wireless anti-theft alarm system is designed to suit the railway transportation system. The research proposes the scheme design, hardware composition, networking protocol and workflow of the system, and discusses the deployment and application of the system, which provides a theoretical reference for the related system construction in the future.

Introduction

At present, the supervision materials of railway transportation are mainly carried out by means of special personnel escort. The requirements for escorts are high, the escort environment is harsh, and there are certain potential safety hazards. In particular, the transportation of important materials such as dangerous goods or weapons and ammunition, once stolen, will be unimaginable. Therefore, it is necessary to design a stable and reliable material burglar alarm system, which enables the escort to timely grasp the state of the door and the entry and exit of personnel. In the event of an abnormality, an immediate response can be made to minimize the likelihood of an accident. The system can actively issue alarms, effectively overcome the lag of discovering the theft of materials, ensure the safety of escort materials to the utmost extent, and reduce the number of inspections, thus reducing the work intensity of escorts.

Current status of railway anti-theft and existing problems

With the rapid development of the logistics service industry and the speed of trains, railway freight transport has entered a stage of rapid development, but at the same time, it has also brought more and more unsafe factors. Theft of railway freight materials is one of the main cause of railway freight accidents. Most of the stolen goods are stolen by criminals on the uphill section of the freight train or on the train station. The traditional method of combating theft of freight materials is half the battle, and the theft of train freight is still a prominent problem that is currently plaguing the safety of railway freight.

In general, railway transportation anti-theft mainly has the following problems: First, the anti-theft device is old, and there is almost no information equipment. At present, railway anti-theft mainly uses mechanical locks, and some locks are old and vulnerable. Intelligent electronic locks or alarm devices are not being used. Second, the quality of escort personnel needs to be strengthened. Some escorts are unclear about their duties, and the implementation of the rules and regulations is not thorough enough. Some escorts have a fluke mentality of laziness and relaxation. Third, the anti-theft work relies too much on escorts. The escort environment is difficult, and the escorts are prone to laxity. Once the escorts relax their vigilance, the burglary work will not be implemented. In the event of an accident, it can only passively wait for the escort to discover.
Anti-theft technology selection

Electronic lock technology. The so-called electronic lock combines the characteristics of the mechanical lock with the radio frequency identification technology. The control panel, mechanical lock, battery and other modules are installed inside the lock. To achieve the unlocking condition, not only the mechanical lock condition but also the radio frequency identification is required. Such a design double anti-theft, effectively preventing the criminals from using the master key to unlock. When the unlocking fails or the radio frequency identification does not match, the electronic lock will send an alarm signal, the handheld terminal receives the alarm signal and then alerts the escort personnel. The electronic lock mainly realizes the switch of the physical lock and signal transmission through the microcontroller. The overall circuit design requires small volume and low energy consumption, and is mainly composed of a main control chip, a radio frequency chip, a power supply module and the like. The block diagram of the electronic lock is shown in Figure 1.

![Electronic Lock Principle Block Diagram](image)

Infrared detection technology. Pyroelectric infrared sensor is an application of infrared detection technology. It has the advantages of strong concealment, easy to be interfered, and high sensitivity. It can detect the infrared radiation fluctuation in the current range through non-contact form. Pyroelectric infrared sensors have both active and passive detection modes. The active infrared sensor has a small detection range, generally point-to-point. If you want to expand the detection range, you must increase the number of infrared sensors. The passive infrared sensor converts the infrared light emitted by the object in the detection range into an electrical signal by the photosensitive element, and then performs corresponding processing. Passive infrared detectors have a wider detection range and higher sensitivity than active detectors. Therefore, passive detectors are generally used to monitor infrared radiation fluctuations.

The pyroelectric infrared sensor is composed of an optical lens, a pyroelectric element, a resistor, a capacitor and the like. The optical filter can filter out interference radiation such as sunlight or light, and only allows infrared light with a wavelength of 7~10μm to pass, which is close to the normal radiation wavelength of the human body. It greatly reduces the detection wavelength of the pyroelectric component of 0.2~20μm. When someone enters the detection range, the human body radiates on the surface of the pyroelectric element, and a voltage is generated due to the temperature difference; when the temperature is constant, the infrared sensor does not operate. Two reverse-series pyroelectric elements cancel out their pyroelectric effects, which improves system accuracy. The schematic diagram of the infrared sensor is shown in Figure 2.
Magnetic detection technology. The door magnetic sensor is a commonly used anti-theft device in the security system. It has the characteristics of small size and high reliability, and is generally used to monitor whether doors, windows, drawers, etc. are illegally opened or moved. It is mainly composed of a wireless transmitter and a magnetic block. The smaller part is a permanent magnet for generating a constant magnetic field and the larger part is the body of the magnetic sensor. There is a reed switch inside. When the distance between the permanent magnet and the reed switch is less than 5 mm, the magnetic sensor does not operate. When the distance between the two is beyond a certain range, the magnetic sensor sends a packet containing the address information. After receiving the signal, determine the position of the door magnetic alarm. In order to reduce the energy consumption, the magnetic sensor only sends an alarm signal when the door is opened, and then stops automatically. Even if the door is always open, no alarm will be generated to prevent the continuous transmission loss of electrical energy from affecting normal use. The door magnetic sensor generally uses a 12V dedicated alarm battery, and a voltage detection circuit. When the voltage is lower than 8V, the indicator light is on, reminding to replace the battery, ensuring the reliability of the monitoring.

Microwave Detection Technology. The microwave object movement detector is equipped with a microwave transmitting and receiving antenna at the same time, which combines the collection and emission of microwaves, and uses the Doppler effect to obtain the difference between the frequency of the emitted and received microwaves, and then processes it through the amplifier, and then converts it into electrical signals to achieve microwave detection. The microwave object motion detector has a wide detection range and high accuracy, and the detection angle is 60° to 90° horizontally, which is mainly suitable for an open space. Microwave has the characteristics of high frequency, short wavelength and easy reflection. It is detected by analyzing the difference between incident wave and reflected wave. The detection sensitivity is high, but it is impossible to distinguish whether the moving object is human. Moreover, microwaves are penetrating to non-metallic substances and are prone to false alarms.

Summary. Because railway transportation in the process of high-speed movement for a long time, the vibration is obvious, and the durability of the detector is high. The detector that is too precise or too sensitive is prone to false alarm or greatly shorten the service life. The space of the train compartment is limited, and the detector does not need to have a large range of detection distance, and the railway transportation time is long, the detector energy consumption is required to be low, and the frequency of battery replacement is minimized. The electronic lock is outside the compartment for a long time, which is prone to damage. The train vibration is likely to cause the door magnetic detector to false alarm. Therefore, the use of infrared detectors as an anti-theft detector for railway transportation has obvious advantages. According to the different transportation requirements and transportation of different transportation materials, the combination of various anti-theft technologies to design the anti-theft system is also a development direction of railway transportation anti-theft.

System design

In response to railway transportation anti-theft requirements, this study applies infrared sensors and wireless communication technology to alert the illegal intrusion and transmit it to the escort’s
hand-held terminal in time. The hand-held terminal sends an alarm signal to the escort and sends the message through the Beidou system short message. Information and transportation conditions are sent to the information system to enable full monitoring of the escort supplies.

**System overall architecture.** In the design of the system, the train car number is corresponding to the MAC address of the 433M router installed in the carriage, and then the infrared monitoring device installed in the train car is used to sense whether there is an intrusion situation. Such as an infrared sensor detecting an intrusion situation, it will generate electricity signal, then converted into a digital signal via the A/D converter and passed to the micro-controller. The 433M network is then used to send the alarm signal from the 433M router to the 433M network coordinator. Finally, the coordinator transmits the information to the escort hand-held terminal through the serial port. The handheld terminal determines the stolen car number through the correspondence between the MAC and the car number and gives an alarm to remind the escort to immediately handle the situation. The Beidou system sends information such as the situation generated during the transportation of materials and the disposal situation of the escort to the back-end information system. The overall architecture of the system is shown in Figure 3. Such a model is more suitable for the current situation of escort. With the further development of unmanned escort in the future, there is no escort in the process of material transportation. The monitoring terminal detects that someone has invaded and will not directly report to the person but directly sent to the information system. The information system will report to the nearby railway public security organs. The system frame diagram is shown in Figure 4.

![Fig.3. Overall system architecture](image1)
![Fig.4. Unmanned system overall architecture](image2)

**System hardware design.** The hardware part of the system is mainly divided into two parts: the monitoring terminal and the hand-held monitoring terminal in the train compartment, and the information transmission between the two through the 433M network. The monitoring terminal is installed near the door of the compartment to facilitate the detection of the entry and exit of the personnel by the detector. The hand-held terminal is carried by the escort.

1) Monitoring terminal hardware design. The monitoring terminal is a small monitoring device installed in the train compartment, which is based on infrared detectors and wireless communication technology. The monitoring terminal comprises: a detector module, a 433M module, a power supply module, a display module, a CPU and a peripheral interface module, and a logical structural block diagram thereof is shown in Figure 5 [5].
The STC89C52 single-chip microcomputer is used as the main control chip of the monitoring terminal. Compared with the traditional single-chip microcomputer, it has the advantages of low power consumption, high cost performance, stable performance and fast calculation speed. And you can continue to install other modules on this basis, such as radio frequency identification, Beidou communication, etc., still maintain good working performance. The pyroelectric infrared sensor is provided with a Fresnel lens at the top, and the detection wavelength is close to the infrared wavelength of the human body radiation, and becomes an infrared sensor specially used for monitoring the radiation of the human body, and then the signal processing circuit based on the BISS000 component is used to output the signal of the sensor. Convert to a digital signal received by the micro-controller. The power supply module of the monitoring terminal is a 5V lithium battery, which has the advantages of small size, reusable use, and stable power supply. In the future, on the basis of the installation of radio frequency identification, RF tags will be attached to the escorts to avoid false alarms when the escorts enter.

(2) Hardware design of hand-held monitoring terminal. The hand-held monitoring terminal is a small hand-held terminal device that is convenient for the escort to carry around, including: Beidou module, 433M module, alarm module, antenna, power supply module, display module, CPU and peripheral interface module, and its logical structure block diagram is shown in Figure 6.
accident occurrence and processing to the information center, and the information center can also
Know the location of the material or send instructions to the escort through the Beidou satellite
positioning system. After the radio frequency identification is widely used in the future, the radio
frequency identification function can be added to the hand-held monitoring terminal to directly record
the escorted material information and then transmit it to the information center.

**System software design.** The rapid development of wireless communication technology enables
the sensor to use the wireless sensor network to transmit the monitored information and the
information to be transmitted wirelessly, and finally to the client terminal, and the networking mode
is different.

(1) Networking Protocol. The railway box car compartments are made of iron, and the longitudinal
distance is long. There are certain requirements for the communication distance and transmission
quality of wireless communication, especially the metal car has a great influence on the signal
transmission. The currently widely used ZigBee wireless sensor network protocol is relatively mature
and free to use. Compared with other wireless communication technologies, ZigBee technology has
the advantages of low power consumption, low cost and simple operation. However, since the
working frequency band allowed by the domestic ZigBee technology is only 2.4 GHz, and the
wavelength band is short, the frequency is high, and the frequency band is crowded. Thus, it has a
problem of weak anti-interference and poor barrier capability. It can be seen that the ZigBee
technology is not suitable for the railway transportation environment.

The SimpliciTI network protocol makes up for the shortcomings of ZigBee. It can work in the 433
MHz band, and the wavelength is longer and the diffraction capability is enhanced, which greatly
meets the special requirements of railway wireless communication. The relationship between data
center, terminal node and range extender in the protocol is shown in Figure 7.

![Fig.7. SimpliciTI protocol device relationship diagram](image)

The data center is responsible for the initiation of the network, the processing and transmission of
data, the maintenance of the topology, and the connection with the hand-held terminal. The terminal
node is responsible for collecting data and transmitting the data to the data center. The range extender
is used to collect information of distant nodes, and the hand-held terminal is mainly responsible for
background network monitoring, controlling network topology and data processing.

(2) System Work-flow. The data center is also called a coordinator in the wireless sensor network. It
has the function of a gateway. After the router or terminal node joins the network, it forms a tree
topology wireless network suitable for railway transportation. The work-flow is shown in Figure 8.
After the router is installed in the car and initialized, it requests to join the 433M network, and then
sends the infrared detector data to the coordinator through the 433M network. The work-flow is shown in Figure 9.
Deploy the application

The on-site monitoring equipment of the system is installed by the material sender after the materials are loaded, and the hand-held monitoring terminal is carried by the escort. After the equipment is installed, the system will be debugged, focusing on the stable operation of the infrared detector, the smooth transmission of the signal and the complete alarm function. Field equipment should be easy to install and disassemble, try not to make too much damage to the train compartment, and facilitate the recycling of equipment. The material sender is responsible for training the escort to ensure that the escort is skilled in operating the system and can respond appropriately to general issues. Both the material escort party and the material recipient are equipped with an information system so that both parties can grasp the status and location information of the material transportation, and can communicate with the escort through the system. Ensure that the system can start transportation after safe and stable operation. During the transportation process, the escorts mainly ensure the safety of materials through the hand-held monitoring terminal, and the number of inspections can be reduced appropriately.

Conclusions

Infrared sensor-based railway transportation anti-theft alarm system, using the Simpliciti protocol to build a wireless sensor network, using infrared detectors to sense the intrusion of personnel, timely make an alarm to the escort to, ensuring the timeliness and accuracy of the alarm. It is completely feasible at the technical level and meets the characteristics of railway transportation. The system is applied to railway transportation, which will make the railway safe transportation more information and intelligent. It can effectively prevent theft of materials, reduce the work intensity of escorts, reduce the number of escorts, and improve the safety and reliability of railway transportation.

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References


