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# Design of Satellite Inspection Terminal for Intelligent Electric Power Patrol System

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**ABSTRACT**

To address difficulties such as high error rate in data collection, untimely data uploading, and the hidden danger of inspectors, this paper designs a satellite terminal for power patrol over rough terrains. Considering the actual application scenario and the existing technology, the function of each module of the inspection terminal is designed and realized. This terminal accounts for various, flexible space-ground integrated communication modes employed both on the ground and satellite, which is easy to operate and has a low-power mode. Besides, it can meet the real-time data upload requirement of power patrol over rough terrains. The terminal is practical, applicable, so it has application prospects in the modern power patrol system.

***KEYWORDS:*** *Power patrol system; Satellite inspection terminal; Module design; Low power consumption*

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## 1. INTRODUCTION

Nowadays, China's power grid construction is more and more comprehensive, and the coverage area is larger and larger. It has become an important part to inspect the power lines and ensure the safe and stable operation of circuit facilities. While ensuring the integrity of the power grid structure, it is also necessary to maintain the power grid facilities. Considering the large area and the complex terrains, the maintenance work of the power grid becomes more inconvenient.

At present, there are mainly two ways of electric power patrol: manual patrol and unmanned aerial vehicle patrol. The traditional manual patrol method is direct and the patrol terrain is extensive, but it is easy to fail to check and record errors. For dangerous and unfamiliar terrain, the patrol inspectors are prone to danger and difficult to call for help in time, which brings great hidden danger to the personal safety of the patrol inspectors. Besides, it is not easy for administrators to check the data uploaded by the patrol inspectors, which makes it difficult to understand the facilities condition fully, make targeted maintenances. And the management of inspectors also becomes difficult. Due to the limited amount of data collected by UAV patrol inspection, the high amount of invalid data, the poor consistency of large-scale collection, the inability to repeat and contrast, and the leak of beat and remake, it is difficult for administrators to organize data. UAV is also affected by terrain and its endurance, and it is difficult to control in complex environments[1][2][3]. In order to solve above problems, it is necessary to design a portable and easy-to-operate satellite patrol terminal for intelligent power patrol system, which can obtain more accurate and effective information for management decision-makers to analysis and warn early, such as personal safety information, route trajectory of inspectors, field temperature and humidity of power grids, current circuit status, and illegal construction.

This paper gives an overview of the power patrol system firstly, then designs a satellite patrol terminal which can collect patrol information in the power patrol system either by satellite or by the ground base station. Finally, the key technologies of the application of the satellite patrol terminal is described.

## 1. Framework of patrol inspection system

The intelligent power line patrol inspection system in this paper includes basic power facilities, administrators, inspectors, daily patrol tasks and so on, which form a ubiquitous power Internet of Things [4][5].

The power patrol inspection system adopts the popular three-layer architecture including perception layer, network layer and application layer[6]. The system architecture is shown in Figure 1. The lower layer provides data or communication services for the upper layer.

When the patrol inspectors perform the patrol task, they wear the patrol terminal, which cooperate with special software in their mobile phone. So the patrol terminal can acquit the data acquisition work on the patrol site. Then the patrol inspectors upload data to the management center of power grid company via satellite or ground network. The management center locates in the computer room, which is responsible for receiving and processing the collected data sent by the patrol terminal, displaying it on the enterprise management platform, and sending the management instructions to the patrol terminal.

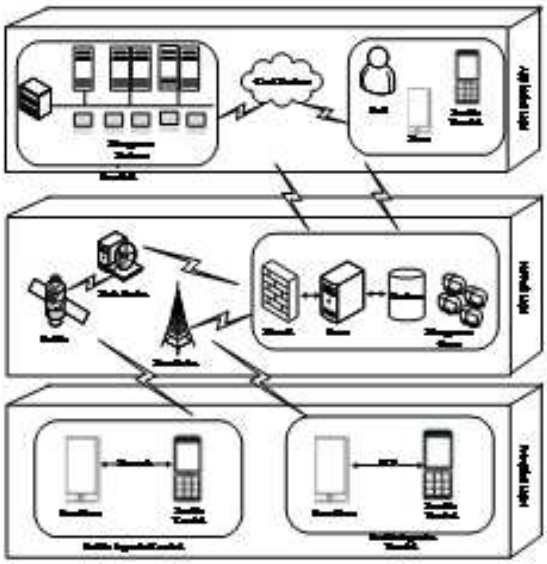

**Fig.1 Framework design of patrol inspection system**

### 1.1. Perception layer

The data in perception layer of the patrol system come from the patrol terminal through collecting on-site information.

The patrol terminal has many function modules, such as Bluetooth transmission, GPS/Beidou positioning, temperature and humidity acquisition, upload and rescue. When starting the patrol task, the patrol terminal is woken up by Bluetooth module and matches with the software. GPS/Beidou positioning module collects and reports the location information of the inspector in real time, and plans the route for him. At the same time, it gives prompts when the inspector deviates from the route. Temperature and humidity acquisition module collects and records environmental parameters during inspection, which is convenient for managers to analyze hidden danger of the inspected objects. The information collected by the patrol terminal reaches the background data management center through upload module. When the inspector encounters an emergency that threatens his own safety, he sends out the rescue signal through the rescue module in time to ensure his own safety.

At the same time, the patrol terminal has other function modules, such as identity authentication, two-dimensional code reorganization, photo and video module, and task management. The patrol inspector completes the identification by identifying ID number and human body characteristics and wakes up the patrol terminal with Bluetooth to start the patrol task. During the inspection process, the inspector can scan the two-dimensional code of the power facilities to see their basic information, record the power facilities comprehensively through voice, photography and video, and then upload all the records to the data management center. The patrol inspectors can view, accept, and cancel patrol tasks through task management module.

### 1.2. Network Layer

Network layer in this system uses the ground network and the satellite network to transmit data and communicate together. When the ground network is smooth, it has become the first choice to transmit data. The satellite network is preferred when the signal of the ground network is weak, poor, or no signal. Considering the wide-area coverage and autonomous flexibility of the satellite network, and low latency and high speed of the ground network, this system forms the transmission mode of Space-ground integration.

### 1.3. Application Layer

The management platform of the provincial power grid company is deployed in the computer room or data center of the enterprise, which can analyze on-site patrol data, manage patrol personals, distribute the patrol strategy and handle early warning of on-site patrol inspection.

Combining the identity of the inspector and the inspection task, it plans the inspection route for the inspector, analyses the unexpected situation reported by the inspector, gives the solution, and distributes the inspection task. Besides, it[7][8] provides graphical data to the administrator so that the administrator can observe all kinds of situations directly in the background, and also provides the means to deal with emergencies, etc.

## 2. Design of Satellite Patrol Terminal

Satellite patrol terminal integrates positioning, baseband and radio frequency modules, etc. The terminal hardware design is shown in Figure 2.

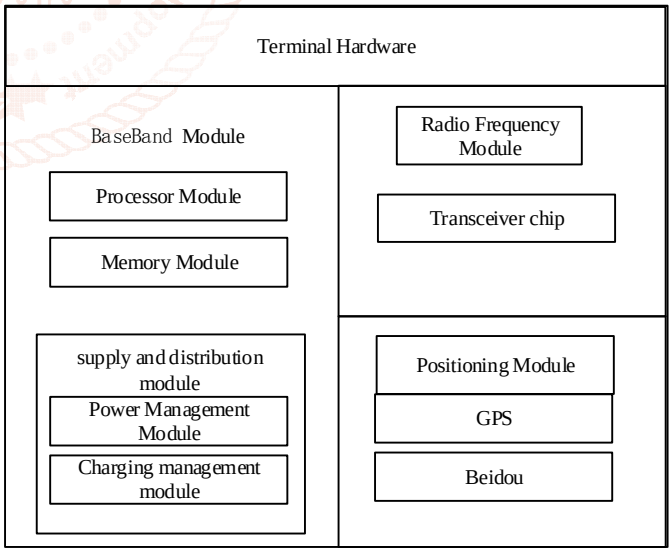


**Fig.2 Terminal hardware design**

Each module of terminal hardware is introduced as follows.

### 2.1. Baseband Module

Baseband Module is responsible for signal demodulation. This module is composed of processor module, memory module and power supply and distribution module. The terminal hardware structure is shown in Figure 3.

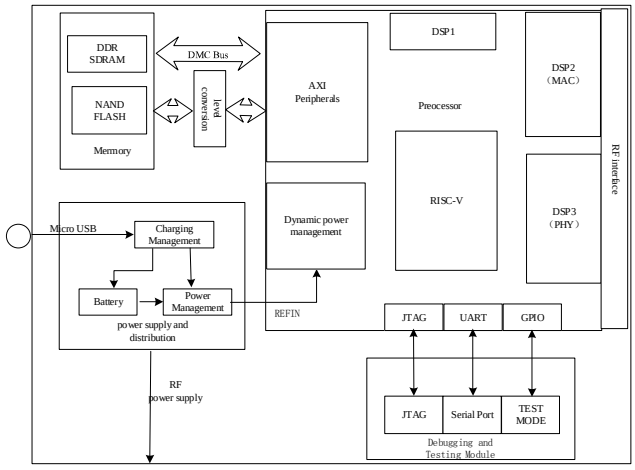


**Fig.3 Design diagram of terminal hardware structure**

## 2.2. Processor Module

The processor module in the patrol terminal takes charge of control function. It also can process data and complete various algorithms of signal processing such as channel coding/decoding, interleaving, encryption/decryption.

This Satellite patrol terminal selects SSTC-5 chip developed by Aerospace Star Technology Co., Ltd. independently. This chip adopts the world's advanced high-speed, low-power, multi-threaded DSP technology. It has the advantages of software compatibility with mobile communication protocols, multiple navigation, positioning algorithms and image processing algorithms, and parallel processing of multiple algorithm steps**Error! Reference source not found.**. It also provides the programmable RF interface, memory card, keyboard, USB interface for application developers. It supports mostly embedded operating system, and terminal hardware operation is guaranteed with memory module.

## 2.3. Memory Module

Memory module stores all programs and data, which can read and write data or program access at runtime. This module adopts Miron's chip. The hardware structure of memory module is shown in Figure 4.

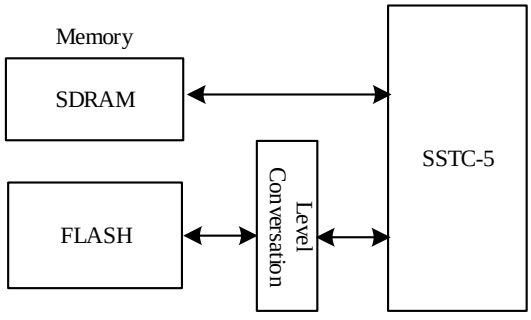


**Fig.4 Hardware structure design of memory**

When Flash is power-off, data in it will not be lost. So Flash is designed for data storage. SDRAM is used for program storage. When the terminal hardware is power-on, the program and required data are transferred from Flash into SDRAM. So all programs can run in SDRAM. Flash connects to SSTC-5 level through level conversion chip to ensure the safety of the circuit.

## 2.4. Power Supply and Distribution Module

The power supply and distribution module has two functions: providing multiple different power supply voltages for each device in the whole terminal hardware; managing battery charging, and reporting the charging status and battery status at the same time. The structural design of the power supply and distribution module is shown in Fig. 5.

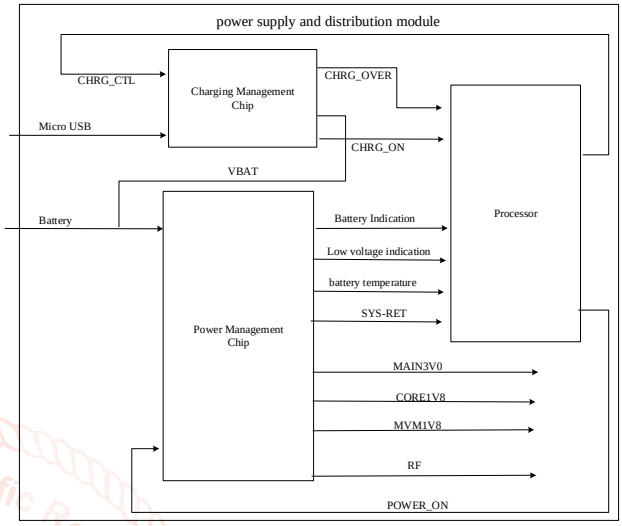


**Fig.5 Structural design of power supply and distribution module**

Due to the voltage variance of different modules, the power supply management module outputs signals to CPU to indicate battery status and then changes the output voltage for voltage management. The workflow of the power management module is as follows. Firstly, POWER_ON signal is generated after SSTC-5 is effectively turned on. Then the power management module outputs a status signal to CPU to indicate the power status and changes the output voltage. The power management module can generate different voltage, such as 2.5V, 1.8V and 1.2V, which can power memory, LCD, radio frequency, main control and other modules.

The charge management module can generate charge control signal CHRG_CTL according to the power indicator BATSUP to control charge. The comparison results of battery voltage and set voltage determine whether the charge management chip generates charge termination signal to CPU, which enables CPU to stop the charge state of the battery through a charge control signal.

## 3. Design of RF module

The RF module is the core component of the terminal hardware communication, which undertakes the function of receiving and receiving RF signals in dual-mode system. This part adopts IRIS404 RF Transceiver chip of ACP Electronics Co.Ltd. The chip adopts zero IF receiving architecture and up-conversion transmitter architecture, which makes it has the advantage of low power. At the same time, it can control and correct radio frequency digitally**Error! Reference source not found.**[11].

IRIS404 chip can send and receive radio signals in L-band and S-band. The upstream and downstream switching of L-

band and S-band is realized by SP4T switch, and GPIO of SSTC-5 controls the RF transceiver switch.

RF module communicates with the core chip SSTC-5 through PSD interface, and its interface scheme is shown in Table 1.

**Table1 Interface archives**

| Interface Type | ACP | SSTC-5 | Description |
|---|---|---|---|
| Rx data bus | RBDP0 [0:11] | PSD1[4:15] | Use the high 12-bit in PSD1 |
| Rx data clock | MCLK | PSD1_CLK | |
| Tx data bus | RBDP1 [0:11] | PSD3[4:15] | Use the high 12-bit in PSD3 |
| Tx data clock | FCLK | PSD3_CLK | |
| SPI | SPI | SPI2 | SSTC-5 is the master device |

The scheme uses PSD interface for data transmission and SPI bus for control information transmission.

## 4. Design of positioning module

GPS and Beidou are used in the positioning module. Dual-mode is more accurate and more conducive to positioning and route planning[12].

UBX-M8030-KT of U-blox Co., Ltd. is used in positioning module. The chip can receive signals in GPS and Beidou concurrently, and its sensitivity is -167dBm. It is characterized by excellent positioning service. When the single-satellite operation is used, the total power of the chip can be as low as 12 mW in the power-save mode, which meets the requirements of low power and high precision of the terminal.

In order to improve the visibility to GPS satellites and anti-jamming ability, low noise amplifier and surface acoustic filter are added to the receiver front-end. And LDS antenna supporting GPS and Beidou frequency is selected to avoid the internal interference of the terminal and ensure the terminal signals [13].

## 5. Key technologies

There are many drawbacks in mostly patrol terminals. Some terminals need recharging frequently and consume a lot of power. Some terminals cannot meet the communication requirements of no blind area and low latency. So the patrol terminal should use the low power consumption design and combine ground communication with satellite communication, which is considered in this paper.

### 5.1. Low Power Design

Low-power design can avoid the inconvenience caused by charging frequently and prolong the service life of the terminal. Besides, it ensures the reliability and performance of the terminals and avoids the influence of thermal energy and thermal noise caused by power consumption on the normal operation of the device. It also reduces the cost of the terminal because low-power design can avoid additional heat dissipation costs in the later period [14]。

The low power design of satellite patrol terminal in this paper has fully considered the requirements of low power consumption from the selection of chips. IRIS404 realizes dual-mode RF transceiver function in L-band and S-band, switches upstream and downstream in L-band and S-band, and chooses a single-pole four-terminal switch specially designed for applications requiring very low insertion loss, high power processing capability and minimum DC power consumption. Baseband module uses SSTC-5 chip. SSTC-5 has the ability to process dense high-speed signals and low system power consumption. Multi-core technology not only improves the processing capacity of the system, but also satisfies fairly the low power requirement. In addition, the heterogeneous organization of chips achieves more optimal allocation of resources than the homogeneous organization, which further reduces the overall power consumption of the system[15][16][17][18].

While on standby, the patrol terminal is in ultra-low power standby sleep mode. It uses zero copy technology, shuts the LCD screen, adjusts ARM applications into low power mode. The DSP modem can control and save power separately. In shutdown mode, the baseband chip is in the deep sleep state, while the LCD screen is turned off, only the interruption of the boot button is reserved, so as to reduce the power consumption of the terminal.

### 5.2. Space-ground Integration Communication Design

Considering the complex terrain of patrol inspection, the patrol terminal is not only designed for ground communication, but also compatible with satellite communication. The patrol terminal has a Space-ground integrated communication scheme.

The ground network has the characteristics of low latency and high transfer rate, which can meet the network transmission and communication requirements of patrol data acquisition mostly. However, in the complex terrain of Power Patrol line, there are some problems such as low coverage rate and weak signals of the ground network, which can not guarantee stable communication and data transmission. Satellites provide more coverage than the ground network through three-dimensional aerial coverage. The integration of space and ground enables patrol terminals to use ground network communication under normal conditions and satellite communication under special circumstances, thus provide a double guarantee for patrol officers' communication[19][20].

## 6. summary

This paper analyses the current situation of Power Patrol line, elaborates on the necessity of the satellite patrol terminal and designs a satellite terminal for power patrol over rough terrains. This terminal has many functional modules, such as baseband, radio frequency, power supply, etc. Finally, the key technologies of the patrol terminal are briefly described.

The satellite patrol terminal in this paper has many flexible communication modes, such as low power consumption and integration of space and ground. It can be widely used in Power Patrol lines with complex terrain. The design of satellite patrol terminal is reliable and has strong practicability and generalization.

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