IOP Conf. Series: Materials Science and Engineering **394** (2018) 032144 doi:10.1088/1757-899X/394/3/032144

Research on Signal Control System of Urban Rail Transit Based on Communication Technology

Wu Wei

Lanzhou Jiaotong University, 730000, Lanzhou, China

Abstract. Moving block system is one of the applied technologies of signal system of urban rail transit, which is usually realized by train control technology based on communication. In this paper, the basic principle, system structure and realization of mobile block system are discussed systematically.

1. Introduction

With the development of urbanization, the number of cars is increasing year by year. Cities have been planning and building three-dimensional rail transit systems, and rail transit has gradually become the first choice for people to travel. It is necessary to shorten the interval of train running time. With the continuous development of computer automatic control and communication technology, the mobile block system based on communication based train control communication-Based Train control CBTC technology is mostly used in urban rail transit.

The definition of moving block system is to realize continuous, large-capacity two-way vehicle-ground data communication by using high-precision and non-track circuit based train positioning technology. A continuous automatic train control system with on-board and side rail processors performing safety functions. The moving block is relative to the fixed block. The control system does not have a fixed block partition.

2. Moving Block Principle

The main use of traditional signal system trackside safety signal, the train stops and the driver's vigilance to keep the actual distance of the train, so that train will not go to a range of other trains has been occupied. In contrast, the moving block system is in the premise of ensuring the safety, by increasing the train positioning resolution and movement authority the frequency of updates to narrow the distance between trains, enhance the capacity.

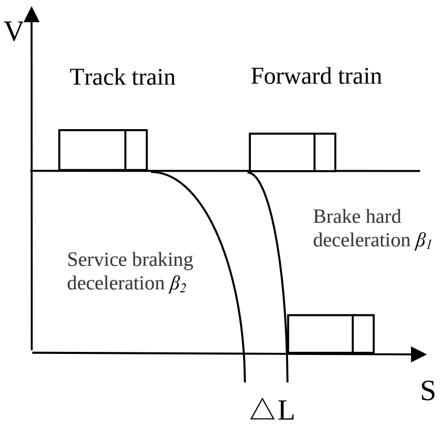
The moving block can be divided into two types. One is a moving block system considering the speed of the forward train. The system is called relative velocity mode, or MB-V mode, according to the position and the speed control interval of the forward train. The train spacing is shown in Fig.1 (assuming that the speed of the two trains is equal). Set the minimum interval between the track train and the forward train as L, and the speed of both. The deceleration time and the airwalk time are V_1, V_2, β_1, β_2, τ_1, τ_2 respectively. The safety distance between two vehicles is ΔL, and the minimum distance between the two vehicles is as follows:

$$L = V_2\left\{\frac{V_2}{2\beta_2}+\tau_2\right\} - V_1\left\{\frac{V_1}{2\beta_1}+\tau_1\right\} + \Delta L \quad (1)$$

The other is a moving block system that does not consider the speed of the forward train. This system does not consider the speed of the forward train, but only the position of the train, so it is called the relative position mode, or MB-V_0 mode, as shown in figure 1(b). In this case, β_1 is infinite and τ_1 is 0. Then the minimum distance between two vehicles L is as follows:

$$L = V_2 \left\{ \frac{V_2}{2\beta_2} + \tau_2 \right\} + \Delta L \quad (2)$$

It can be seen from formula 2 that the following train speed can be calculated by the minimum interval distance L between the two trains from the deceleration β_2 and the empty walking time τ_2 of the local train, without regard to the forward train speed. Compared with the relative speed mode, the tracking interval of the relative position mode is shorter and the efficiency is higher. It will increase the driving danger, which puts forward higher requirements for the operation control system.



(a) MB-V Method (b) MB-V_0Method

Figure 1. Train tracking control principle of moving block system

3. System Structure of Moving Block

The system structure of mobile block is usually divided into three levels: management layer, operation layer and control layer. It removes all sections from the signalling machine. The moving block can flexibly complete all ATC functions under three-level monitoring, as shown in figure 2.

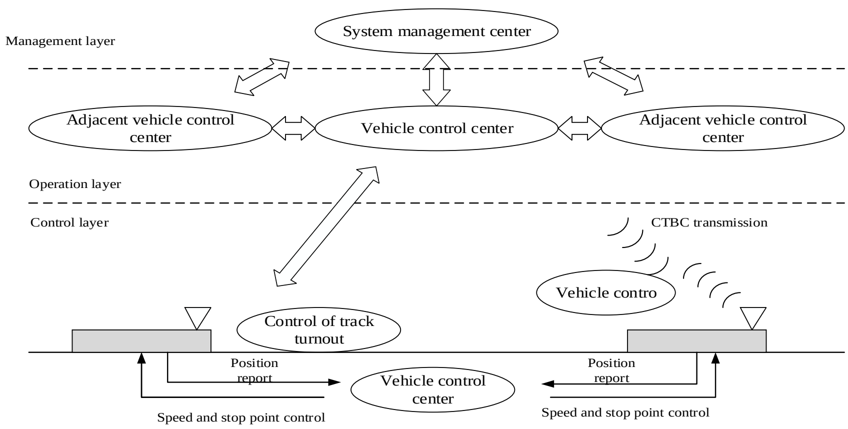


Figure 2. Three-layer control structure of moving block

The system Management center is located at the management level. The task of the system management center is to unify the command and control of the train running in the whole line through advanced network technology, and to realize the function of ATS and other central dispatching functions. The vehicle Control center is located in the operation layer. According to the instruction of SMC, the train running interval is controlled according to the principle of moving block, and the train is connected with the interlocking equipment of the station. The train is arranged to connect the departure route. VCC and SMC through the modern communication transmission system. The vehicle On-Boadr Controller is located in the control layer, which realizes the function of ATP/ATO through continuous communication with VCC. Control train safe and high speed operation. Communication mode can be wired communication (such as cross-induction cable) or wireless communication (such as spread spectrum communication).

The on-board computer with redundancy check enables the train to be controlled within the speed and distance defined by VCC, and sends back the position and speed of the train to the VCC in the form of data communication. Each train is equipped with a redundant on-board control system. If one fails, the other starts automatically. In the three-tier structure of the moving block system, the train control center VCC is in the key position. It is responsible for controlling the safe train spacing and route interlocking. Its secure redundant computer periodically exchanges data with the on-board controller through the communication subsystem. VCC is transmitted according to the on-board controller. The position and speed information of the returning train, as well as the line parameters of the train operation, the occupation of the road entry, the turnout state and the stop condition of the platform determine the current maximum allowable speed and safe parking point of the train. The information of the allowable speed and the safe parking point is fed back to the on-board controller of all trains in the VCC control area. Since VCC fully considers the safety of the train operation when calculating the maximum allowable speed. It tracks the smooth running of the train and the comfort of the passenger, so the distance between the tracking trains is the best.

4. The Realization of Moving Block

In the IEEE standard of CBTC functional requirements, the definition of the characteristics of CBTC has a high-resolution train positioning method independent of track circuit, continuous, large-capacity, two-way vehicle-ground data communication. The on-board and side rail processors perform critical tasks. Thus, the realization of a moving block control system that guarantees the high speed, safety and high throughput of a train must have a high precision, high reliability method for locating and measuring the speed of the train, which can be continuous and stable. Large amount of vehicle-ground two-way communication, which can be achieved through advanced wired and wireless communication technology.

4.1. Implementation Using Cross-induction Cables

The use of rail continuous speed control system using cross induction cable rail cable car - communication, the indoor and outdoor equipment control two levels to achieve its aims. Repeater control center and the setting is connected to a plurality of along the line, a repeater is connecting with multiple rail cable loop. The structure of the system is shown in Figure 3.

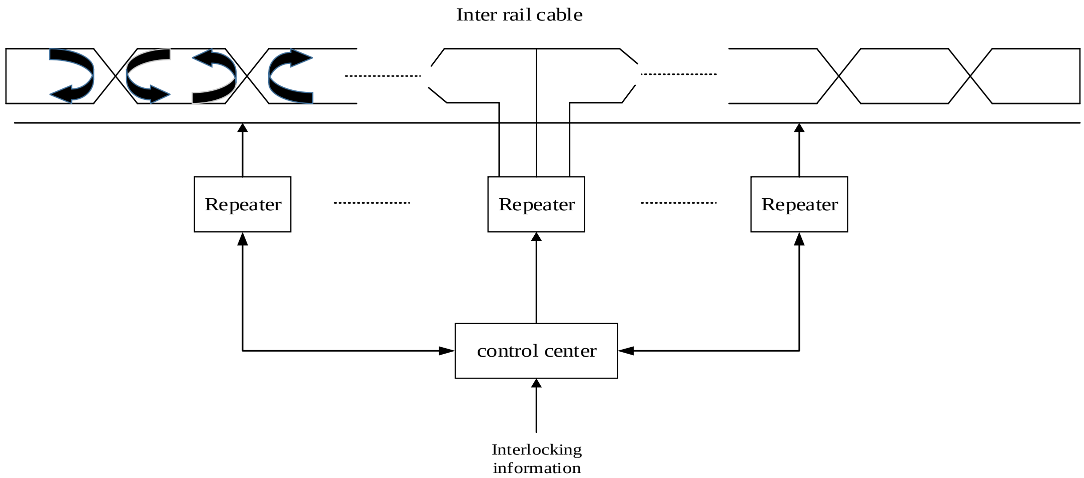


Figure 3. Two-stage control structure with interrail crossing cable

An induction cable is laid between the tracks, one line is on the track bed in the middle of the track, and the other line is below the rail to the waist, and the cable crosses at intervals. The purpose is to counteract the interference of the traction current and to realize the train positioning. The interrail cable is the only information channel between the train and the ground, and the information in the cable is usually transmitted by frequency shift keying (FSKK). The transmission rate varies according to the technical specifications of various equipment. When the train passes through each cable intersection point, it detects the phase change of the signal in the loop through the on-board equipment, and counts the number of the phase changes. Thus the accurate positioning of the train can be realized by interrail cross induction cable. The advantages of continuous transmission of information from ground to ground on board are simple realization and strong anti-interference ability, but this way requires expensive cables to be laid, and the cable feeding route between tracks is inconvenient, which is its deficiency.

4.2. Implementation Based on Leakage Coaxial Cable
Leaky Coaxial cable is a coaxial cable with a certain shape and spacing slot opening on the outer conductor. The energy of electromagnetic field is concentrated between the inner and outer conductors of the coaxial cable, and the control center emits electromagnetic wave along the cable. The electromagnetic wave radiates from the outer conductor slot to the outer leakage field, and the train obtains the frequency conversion energy to communicate with the ground. Similarly, the train emits electromagnetic wave and produces the leakage field outside the cable, which is also coupled to the cable to communicate with the control center. In order to achieve bidirectional communication and extend the transmission distance, the corresponding relay segment is inserted in both directions. The gain of the relay can compensate for the transmission loss of the cable in the relay segment.

4.3. Use of the Global Positioning System
The Global Positioning System (GPS) is generally composed of three parts: GPS satellite, ground monitoring system and GPS receiver. The GPS satellite has 24 and 3 spare satellites scattered on six orbital planes to ensure any time and place on Earth in order to ensure any time and place on the earth. The pseudo-range signals from 4-9 GPS satellites are received by the GPS receiver for positioning. If the GPS receiver is installed in the front and rear of the train separately, the current positioning accuracy of the train can be about 10 m. The precision of differential GPS is less than 5 m. The main technical difficulties of positioning mode, such as simple equipment, small size, convenient intenance and low cost. The positioning accuracy is not enough to ensure the reliable discrimination of trains on parallel tracks.

4.4. Inertial Positioning system
Inertial positioning system (Inertial Positioning System, IPS) positioning by induction of inertial components installed on the train on the train in the operation of the acceleration through computer operation to get the train position, speed, and direction positioning parameter. IPS is a fully autonomous positioning, its adaptability, sampling rate, data output the frequency and accuracy of measurement within a short period of time is also very high, which can also be used for the measurement of various positioning parameters. However, due to the IPS positioning method belongs to the calculation formula; the positioning error will increase with time, which subject to external positioning information input repair. Therefore, IPS is usually used in conjunction with GPS, query transponder and other positioning methods. TIPS (Train Inertial Positioning system) is from US&S Corporation, USA.

4.5. Vehicle Doppler radar Positioning System
According to the Doppler principle, the train is measured. Doppler radar is installed along the line. When there is a section occupied by the vehicle, the radar antenna transmits ultra-high frequency electromagnetic waves to the moving vehicle, and the electromagnetic wave reflected by the car body is received by the same antenna. The difference frequency between the transmitted electromagnetic wave and the received electromagnetic wave is taken out by the mixer. According to the Doppler principle, the difference frequency is proportional to the train speed. The difference frequency is sent to the main control room of the station, and the difference frequency is simulated or digitally measured by the main dispatching computer. The train speed and position information are measured according to the radar antenna number. The ASTREE system developed by France National Railway is realized by this method.

4.6. Location of Wireless Spread Spectrum Communications
The location of wireless spread spectrum communication uses the spread spectrum multiple access technology in wireless communication. Spread spectrum communication is to transmit the information to be transmitted; the data is modulated by pseudo-random coding sequence, that is, spread spectrum sequence, and then transmitted after spectrum spread. The receiver uses the same coding sequence to demodulate and process the original data. Train positioning is realized by measuring the radio propagation signal between the same rail side equipment. The positioning accuracy is related to the frequency of the spread spectrum signal. The higher the frequency is, the more accurate the location is. BART (Bay Area of San Francisco Bay MRT Rapid Transit-based) AATC (Advanced Automate Train Control) system is a wireless spread spectrum location system, which is shown in figure 4.

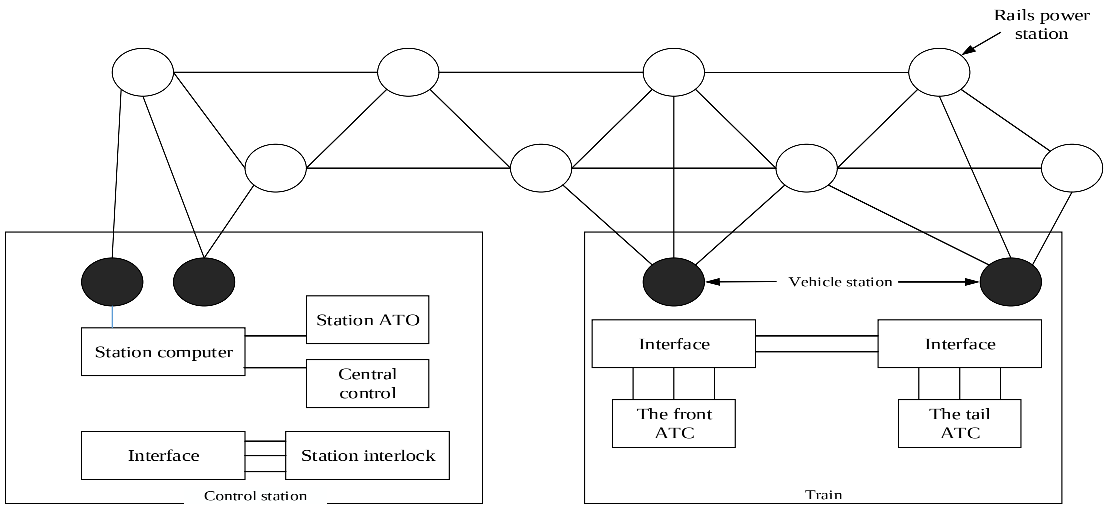


Figure 4. AATC system block diagram

On the one hand, the spread spectrum station of platform, side track and train are used to transmit information between the train and the control center. On the other hand, it is used to locate the train. The position of the train is calculated by receiving the signal from the spread spectrum station beside the track. Instead of dividing the track into different control areas through the mileage measurement, AATC system's each control area is controlled by a station computer. In the AATC control area, a wireless communication network is composed of a distributed radio station, and each control area alternates with each other. The system can detect every train every 0.5s, and the accuracy of train positioning can reach 1.8m.

5. Conclusion

Wireless communication technology is leading the urban track signal control system into a new stage of development; especially the standards-based wireless local railway communication signal technology has been developing maturely. The signal system can take advantage of the third party wireless communication platform. WLAN did not only provide physical layer and data link layer service, but also provide network layer and transport layer service protocol, which makes vehicle-ground communication more transparent. Control is more convenient and through the combination of specific projects as the control system develops rapidly. Through the application of specific projects, the problems that cannot be found in the research have been solved. With the continuous improvement of the level, through digestion, absorption and exploration, domestic systems will be more safely used in train control. Meanwhile, the technology is becoming more and more perfect.

References

[1] Meng Fan-jiang, Li Xiaodong. Train Monitoring and tracking function of CBTC [J]. Railway Communication signal, 2007, 433N: 14-15.
[2] Ji Kaiquan. Analysis of moving block system based on Suzhou Rail Transit Line 1 [J]. Sci-tech Information 2011.
[3] An Jing, Wang Ling-qun, Wu Wenq. Overview of research and application of wireless communication based train control system [J]. Journal of Shanghai Institute of Applied Technology (Natural Science Edition, 2016, 02: 132-138).
[4] Liang Dongsheng, Xu Y. Implementation of the minimum tracking interval analysis and simulation algorithm for trains under CBT train control mode [J]. Modern Urban Rail Transit (MURT): 20114: 5-7.