Study on the methods of shortening the response time of the Radio Based Cab Signaling system

J. Wang, Y. Zhang, H. Wang & X. Wang
Automation Research Institute of Transportation Science & Technology, Beijing Jiaotong University, P. R. China

Abstract

Radio Based Cab Signaling (RBCS) is a kind of device that transmits cab signaling and train control information by means of radio. It consists of two parts: the station control equipment and the onboard equipment. The station control equipment collects the information generated by station interlocking, and then transmits the information by radio to the onboard equipment which displays the information to the driver and at the same time sends it to the onboard ATP equipment. RBCS can use either a commercial radio data transceiver or a GSM-R network as the transmission media.

The response time of RBCS is defined as the time period from the generation and transmission of the cab signal by the station control equipment, to the display of the information on the signal machine in the cab. The response time is an important index of RBCS, because it is closely related with train operation safety and traffic efficiency.

In this paper, the scheme of an approaching continuous RBCS based on a radio data transceiver is proposed, the control method of RBCS is described and the methods of shortening the response time of RBCS are analyzed in detail.

Keywords: radio based cab signaling, response time, interwoven technique, communication based train control.

1 Introduction

Communication Based Train Control (CBTC) system is the development trend of train control techniques, which has many advantages when compared with the Track circuit Based Train Control (TBTC) system. For example, bi-directional
train-track communication with large information volume can be realized; close-looped control can be formed to improve train operation safety; moving block can be implemented to enhance traffic efficiency.

Chinese Ministry of Railway (MOR) is now advocating CBTC techniques, and has made a plan to develop Chinese Train Control System (CTCS) which is now under stepwise implementation. CTCS consists of five application levels, from level 0 to level 4, in which level 3 and level 4 will be based on CBTC. In the near future, part of the CBTC techniques will be applied on Qinghai-Tibet Railway and Datong-Qinghuangdao Railway.

The Qinghai-Tibet Railway is built on a plateau with perennial frozen soil and very harsh climate. The lowest temperature is −45.2°C and the maximum temperature difference is 35°C. Under these conditions, the outdoor signaling equipment, especially the track circuit will work unstably, and its insulation joint will be easily damaged. To the Datong-Qinghuangdao Railway which is a dedicated coal line, a transport capacity expansion plan will soon be carried out, with the goal to increase train weight from 10,000 tons to 20,000 tons. As a result, the traction current will reach as high as 1000~1500A, causing the unbalanced current to exceed the standard by a great margin, which will directly affect the normal operation of track circuits. In view of above situations and considering the future development of Chinese railway, MOR has decided to use radio to transmit train control information, and has started the research on Radio Based Cab Signaling (RBCS) system which is now under experiment.

RBCS is a kind of device that transmits cab signal and train control information by means of radio. It consists of two parts: the station control equipment and the onboard equipment. RBCS can use either commercial radio data transceiver or GSM-R network as the transmission media.

RBCS can replace track circuit to realize bi-directional train-station data transmission. The station can send cab signal and dispatching instructions to the train, while the train can send its speed and position, together with the return receipt of the cab signal to the station.

RBCS can work with onboard ATP equipment, interrogator/balisles, station interlocking, axle counters and so on to realize close-looped train control. As a result, train operation can be continuously tracked and monitored, thus enhancing train operation safety, reducing the number of trackside equipment and lowering the maintenance cost.

There are two types of RBCS. One type is called continuous RBCS because it can provide cab signal all the way when a train is running either between stations or within a station area; another type is called approaching continuous RBCS because it can only provide cab signal when a train is running within a station area.

This paper will focus on the main factors affecting the response time of the approaching continuous RBCS based on commercial data transceiver and the methods of shortening the response time.
2 Main factors affecting the response time of RBCS

The response time of the cab signaling is defined as the time period from the generation and transmission of the cab signal by the station control equipment, to the display of the signal information on the signal machine in the cab. The response time is an important index of RBCS, because it is closely related with train operation safety and traffic efficiency. The shorter of the response time, the more efficiency will be gained in the manipulation of the driver. Under emergency situations, emergency brake can be applied to guarantee train operation safety. The higher of train speed, the shorter of the response time is required.

For the track circuit based universal cab signaling now widely used in China, its control method can be described as one-to-one, which means, at a given time, one track circuit is related to one train, therefore, the response time depends on what kind of track circuit is used and how fast can the onboard equipment interpret the received signal. For example, to the frequency shift type track circuit, such as UM71, the response time is 1.7~2.3s.

The control method of RBCS is essentially different from that of track circuit based cab signaling. In RBCS, a centralized one-to-many control method is adopted, which means that one set of station control equipment can control all the trains within the station area. Normally, a polling method based on time division multiplexing is adopted, thus one control period is divided into several control slots with each slot allocated to one train, as shown in figure 1. Therefore, the response time of RBCS equals to the length of one control period.

The response time of RBCS is affected by many factors, such as the number of controlled trains, the transmission rate, the information volume, the fault tolerance measures adopted in the transmission, the switching time between transmission and receiving status of the data transceiver, the information confirmation method between train and station, the polling sequence of the station control equipment in talking with the trains and so on.

<table>
<thead>
<tr>
<th>Train 1</th>
<th>Train 2</th>
<th>...</th>
<th>Train N</th>
<th>Registration Slot</th>
<th>Train 1</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans</td>
<td>Recv</td>
<td>Trans</td>
<td>Recv</td>
<td>Trans</td>
<td>Recv</td>
<td>Trans</td>
</tr>
</tbody>
</table>

Figure 1: The control period of RBCS.

3 Methods of shortening the response time of RBCS

Following are the methods of shortening the response time of the approaching continuous RBCS based on commercial radio data transceiver.

(1) Method one is to choose the radio data transceiver with fast transmission rate and short switching time between transmission and receiving status.
(2) Method two is to adopt inter-woven technique. The increase of transmission rate will result in the increase of error rate on exponential basis. Therefore, it is not practical to shorten the response time by enhancing the transmission rate. We propose a method of shortening the response time under given transmission rate and specified error rate, which is in fact a technique adopted in the error control of the radio transmission channel. According to survey, the data transmission of RBCS is mainly subjected to the influence of burst errors caused by fast fading, resulting in repeated request of data transmission. Therefore, short frame structure and FEC technique should be adopted in the data transmission of RBCS. Using short frame structure is an effective way to avoid the interference of fast fading. FEC can be used to lower the error rate to required standard. It is well known that the inter-woven technique is mainly used to improve voice communication quality by equalizing the error rate. Although adopting interwoven technique is of use to the reduction of error rate, it is an effective measure to enhance the error correction efficiency of FEC, saving the data transmission time, and finally shortening the response time of RBCS. The detail of the method is described as following.

In order to meet the error rate requirement of RBCS, in the FEC information redundancy code (n, k), the ratio between the length of effective information k and the length of the redundancy information (n-k) must be specified according to the local maximum fading, in order to produce adequate redundancy information to get the due effect of FEC. However, if the information is interwoven beforehand, the local maximum fading can be scattered, thus less redundancy information (n-k) is needed to get the same error correction effect. In this way, the transmission volume can be reduced, thus shortening the transmission time. Correspondingly, the length of a control slot is shortened, resulting in the shortening of the response time of RBCS. For example, in order to correct the same burst error, to the FEC without adopting interwoven technique, the BCH (31,16) code should be used to correct the burst errors with the burst length \( l_b \leq 7 \text{ bits} \), to obtain the coding efficiency of 0.52; to the FEC with interwoven technique, the RS (16,12) code can be used to correct the burst error with the burst length \( l_b \leq 3 \text{ bits} \), to obtain the coding efficiency of 0.75. If the transmission rate is 2400bps, the length of the effective information is 160 bits, the FEC with interwoven technique can improve the transmission efficiency by 31%, shortening the radio transmission time by 20ms, and shortening response time for controlling 5 trains by 1s. Thus, an obvious effect can be achieved.

(3) Method three is to use changeable control period and changeable sequence of time slots. The RBCS station control equipment adopts a polling method based on time division multiplexing to control all the trains within the station area. Thus, the control period T is divided into \( n \) control slots, namely \( t_1, t_2, \ldots, t_n \), with each slot allocated to one train. One control slot consists of following parts: the time for the station control equipment to receive the information from the station interlocking, the time for generating cab signal
information, the time for transmitting the cab signal to the onboard control equipment as well as receiving the information sent from the onboard equipment, such as train position and speed, the return receipt of the cab signal information and so on.

Normally, the capacity of the RBCS station control equipment is designed according to the required maximum number of controlled trains, thus, the control period is fixed to n control slots. However, the number of trains within a station is not fixed, instead, it is only half of the maximum number at most of the time. Therefore, it is a waste of time to use fixed control period. Following methods can be used to solve this problem.

(a) Using changeable control period. A train registration method is adopted to determine the control period, namely, the number of control slots depends on the number of registered trains, as shown in figure 2. Therefore, the control period is changeable during the train control process. This method can not only meet the requirement of controlling the maximum number of trains, but also shorten the response time of RBCS in most cases. The implementation is to use a linked list data structure, the newly arrived train will be registered and added in the linked list as a node; the train which has exited a station will be deregistered and deleted from the linked list.

Figure 2: Time slots allocation in the changeable control period.

(b) Using changeable sequence of time slots. The station control equipment of RBCS receives information from the station interlocking at a fixed time interval. If the cab signal for a train has changed, the station control equipment will immediately set the priority of that train to the highest level, change the original polling sequence, and put the control slot of the train to the front end of the control period. In this way, the train with the changed cab signal information will be treated timely, without waiting for its due sequence. As a result, the response time of RBCS can be greatly shortened. This method can be implemented by changing the pointer of the linked list.
4 Conclusions

In this paper, the scheme of the approaching continuous RBCS based on commercial radio data transceiver is introduced, the main factors affecting the response time of RBCS is discussed, and three methods of shortening the response time is proposed. The results of the field test of RBCS carried out from September 2001 to August 2002 have proved the effectiveness of these methods.

References


