As signal systems on regional lines are aging, we are now proceeding with development of a train control system that can achieve cost reduction and secure safety, taking into account the current situation of regional lines. The main functions of the system under development include block control for single lines using radio transmission between the wayside system (station equipment and level crossing devices) and onboard units, SPAD (signal passed at danger) and overspeed prevention and level crossing control. The onboard unit detects its own position according to information from the line database and performs train stop control up to reaching the stop signal using speed check patterns. The wayside system makes block control based on the train position and train ID information. The level crossing controller activates and deactivates the level crossing alarm according to train position information received from the train. At this point, we have completed production of prototypes of the devices and on-site test runs of those.

**Keywords:** Regional line, Radio communications, Train control, Onboard database, Level crossing control

## 1 Introduction

In the operation area of JR East, there are 33 line sections of approx. 2,300 km in total length called "regional railway lines (regional lines)", which are usually less active with small volumes of transport. Most of these are single lines that are mainly operated with a semi-automatic block system. The semi-automatic block system was introduced in around 1980s as part of line section management improvement by Japan National Railways (JNR), the forerunner of JR East. JNR introduced an electronic blocking system using electronic devices (electric token block) in 1986. As more than 25 years has passed since the introduction of the electronic blocking system, time for those devices to be updated is approaching. JR East is thus developing a train control system for regional lines that makes use of general-purpose radio communications technology and existing technologies. In this article, we will cover the background and concept of the development as well as the overview, configuration, main functions and prototypes of the system.

## 2 Background of the Development

For current regional lines, operation control information for train protection systems such as signals, train detectors, block equipment and ATS and for level crossing protection systems is transmitted via numerous cables. These systems and equipment include many devices to be laid on the ground such as ATS-SN (or Ps) beacons and electronic train detectors. The number of those wayside devices therefore inevitably increases when taking overspeed prevention measures, level crossing safety measures and other necessary safety measures (see Fig. 1).

Increasing the number of wayside devices results in greater installation and maintenance costs, which can be a pressing factor on line section management of regional lines with small volumes of transport. For regional lines where further decrease of transport is inevitable, it is quite important to maintain facilities at a low cost.

## 3 Development Concept

On the other hand, the electronic blocking system that JNR developed to improve management efficiency of regional lines is still in use on four line sections of JR East, specifically on the Koumi line, Ofunato line, Yamada line (Miyako–Kamaishi section) and Gono line. But the devices of the system are increasingly aging as more than 25 years has passed since the system was introduced.

In Europe, ERTMS (European Rail Traffic Management System), a radio train control system using the GSM-R (Global System for Mobile communications-Railway) mobile phone network for railways has been developed. Such systems using radio communications are becoming common worldwide.

In light of those circumstances, we started development with a goal of introducing a system that will enable safety improvement at a low cost in time for the replacement of aged equipment.

### 3.1 Cost Reduction

This system significantly reduces the amount of control cables...
that need to be laid at the wayside by applying radio communications between the wayside system and onboard units. The same radio communications is also used to control the blocking function, signal and train detection function and level crossing control function, so those functions could be concentrated in this system to reduce introduction and maintenance costs.

3.2 Securing Safety
This system makes use of radio communications. As it is equipped with a speed check type ATS function using the onboard unit’s database, it has fewer wayside devices, thus securing safety at minimum cost.

3.3 Highly Flexible and Expandable System Configuration
This system is designed so functions used by individual lines can be selected and added. These functions are achieved by programs. It is therefore a flexible and expandable system where operational conditions can be arranged by adding or modifying the data.

4 System Overview

Fig. 2 shows an overview of the system configuration. The system consists of onboard units, a wayside system (block control device, centralized interlocking device), level crossing controllers, and digital radios (base terminals and onboard radios).

The basic functions are as follows.

4.1 Wireless Communications between Station/Level Crossing and Trains
Using newly developed dedicated radios, information is exchanged between trains and base facilities such as stations and level crossings.

4.2 Train Positioning
Trains identify their own positions based on the position information from batteryless wayside beacons (transponders) and travel distance calculation with a tachometer generator. Using arbitrarily placed batteryless wayside beacons, trains correct positioning errors that occur in running to accurately identify their position.

4.3 Block Control Function
The majority of regional lines are operated with a block system that allows only one train to occupy a section between two stations. Train collisions are prevented in this way. Since these line sections have no need for high traffic density operation as in the greater Tokyo area, we use a fixed block system where a block is set up per section between two stations, as is currently used. Control of blocks (protect/release) is done by checking entry to and exit from the section between two stations.

In a semi-automatic block system, check-in and check-out are controlled using two short track circuits. In an electronic blocking system, however, blocks are controlled using electronic codes and station yard track circuits. In this new system, blocks between stations are controlled using position information held by trains and ID information (car ID) that identifies individual trains.

4.4 Train Location Tracing
Based on position information sent from onboard, the wayside block control device traces the positions of vehicles that occupy a given radio communications area. The block control device recognizes the locational relationship between the trains within the tracing area. If a vehicle that has lost its directional information after parking asks the block control device for its position, the controller transmits position information re-calculated for the position of the leading car taking into account the train length.
The following are the individual controllers and their functions.

5.1.1 Wireless Controller
Main functions of the radio controller are as follows.
(1) Control of transmission to and from the onboard unit
(2) Calculation of the train position
Based on the location information from the batteryless wayside beacons, the controller calculates the distance using information from the tachometer generator. Then it crosschecks with the line data to calculate the train position.
(3) Generation of messages to make patterns
(4) Transmission of messages to the train controller
(5) Correction of train set information and car ID information etc.

5.1.2 Train Controller
Main functions of the train controller are as follows.
(1) Reception of messages
(2) Generation of speed check patterns
(3) Issuing commands for speed check and braking etc.

5.1.3 Speed Control by the Onboard Unit
(1) Control for Stop Signals
The onboard unit wirelessly transmits the train position and car ID to the wayside block control device to conduct block control. The unit receives from the block control device stop limit information according to signal aspects, and it controls braking by generating a speed check pattern to prevent overrun of the stop signal.
(2) Control for Level Crossings
The onboard unit wirelessly transmits the train position, car ID, train set information and speed information to level crossings for level crossing control. The unit receives from those level crossings operational information such as alarm activation and obstruction information for level crossings. If there is obstruction, the onboard unit controls the pattern to make the train stop short of the crossing. If the crossing alarm is working properly, the onboard unit modifies the pattern to allow the train to pass the crossing.
(3) Control for Speed Limit at Curves and Turnouts
For speed limit at curves and turnouts, onboard units make speed limit patterns based on the train position and the data stored in the onboard units. They thus control braking to prevent overspeed.

5.1.4 Database
Onboard devices have the following data to refer to for operations such as generating patterns.
(1) Car data: Data unique to cars and car IDs
(2) Line data: Data on the route and equipment on the track
(3) Message data: Data on message details and location where the messages are generated
(4) Radio transmission data: Data on base terminals
(5) Wayside beacon data: Data on position correction transponders
5.2 Wayside System

Fig. 6 illustrates the system configuration of the wayside system. Wayside system components consist of a block control device and a centralized interlocking device installed in the central signal house along with radio controllers and field device controllers located in the signal houses of individual stations. In the dispatcher's office, an ID display panel and an interlocking control panel are installed to show dispatchers train information and allow operation by dispatchers.

Information is transmitted between onboard units through a train line via electronic couplers.

Fig. 4 Information Transmission between Cars and Train set Information

5.2.1 Functions of the Block Control Device

The block control device has the following functions.

1. Implementing block control between stations on the whole line section and acquiring information on line occupation of trains between stations
2. Transmitting between-station blocking status to interlocking devices
3. Receiving information on interlocking conditions and field device conditions (directions of turnouts, on/off of track circuits, etc.)
4. Receiving car IDs and position information of trains from radio controllers at stations to identify and trace trains running on the line section
5. Generating information required for train control of the trains being traced
6. Transmitting information required for train control to radio controllers at stations
7. Displaying information of trains being traced on the ID display panel and processing the information input to the ID display panel

For the wayside block control device, we will introduce a method where a single central block control device conducts control of all blocks of the entire line section.

In order to deal with the condition of facility such as optical cabling at system updates including replacement of aged station interlocking devices, we are studying a type of system where block control devices are located at stations and conduct control there.
5.2.2 Functions of the Centralized Interlocking Device
A centralized interlocking device can take total control of line sections with a small number of routes. That reduces cost over installing interlocking devices at individual stations on regional lines. We will add the following functions to existing devices.
(1) Transmitting information on line occupation and signal aspect to the block control device
(2) Receiving between-station control information from the block control device

5.2.3 Functions of the Radio Controller
The radio controller has the following functions.
(1) Transmitting information from the block control device to base terminals
(2) Transmitting information from base terminals to the block control device

5.2.4 Functions of the Field Device Controller
The field device controller has the same configuration as that of the existing centralized electronic interlocking device. It has the functions of controlling field signals and point machines by output from the centralized interlocking device and transmitting line occupation information of track circuits to the centralized interlocking device.

5.2.5 Prototype of the Wayside System
The prototype of the wayside system is shown in Fig. 7 and 8.

within the station yard. Test conditions (turnout direction, track circuit conditions) can be set as needed.

Fig. 9 Example of an Interlocking Control Panel Monitor Screen

Fig. 10 Example of an ID Display Panel Monitor Screen

5.3 Digital Radio
Wayside base terminals are in a duplex system, and onboard radios are simplex system. By using general digital commercial radio technology, we are aiming to achieve a relatively low-cost radio.

5.3.1 Radio Functions
The frequency is the 400 MHz band that has shown good results in applications such as train radios. The transmittable distance is around 1.5 km from a base terminal, taking into account the margin of delayed transmission start. A maximum of four trains can simultaneously communicate with a base station at the transport volume and patterns of regional lines in the operation area of JR East.

5.3.2 Prototype Radios
Prototypes of the radios are shown in Fig. 11.
5.4 Level Crossing Controller

5.4.1 Functions of the Level Crossing Controller

Level crossing controllers have the following functions.

(1) Receiving information such as train positions and train set composition from trains via level crossing base terminals
(2) Activating alarms according to train position information
(3) Deactivating alarms according to train position information
(4) Transmitting alarm information to base terminals

An onboard unit generates in advance the stop pattern for stopping short of the crossing and does not correct the pattern unless it receives alarm start information from the level crossing controller. So, the train stops if it does not receive alarm start information. In this way, trains are prevented from passing in situations such as level crossing interference or failure (see Fig. 12).

For sections with crossings at short intervals, a level crossing controller controls two or more crossings with this system.

5.4.2 Prototype of the Level Crossing Controller

Fig. 13 shows the prototype of the level crossing controller. The dimensions of the controller are equivalent to those of the existing electronic level crossing controller (type-M level crossing controller), allowing the controller to be accommodated in the level crossing cabinet.

6 Future Functional Expansion

As functional expansion for further cost reduction and train safety improvement, we are planning to study and develop to achieve the following functions.

6.1 Switch to Onboard Signals

As the system can wirelessly and continuously transmit stop limit information from the wayside system to onboard units, we will study on the feasibility of switching to onboard signals.

6.2 Train Detection not Based on Track Circuits

Line occupation is detected based on the train position information and length information from the onboard unit at a level on par with detection using track circuits. This system would be applicable to line sections without track circuits such as station yards and current non-automatic block sections, so we will study feasibility of the system. We also aim to achieve train detection that is not based on track circuits by introducing this system to line sections currently using track circuits for train detection.

6.3 Operation Notice and Temporary Speed Limitation

Operation control and temporary speed limit information is input at the dispatcher’s panel and wirelessly transmitted to train crew onboard. The onboard unit generates the speed limit pattern in the section involved based on the transmitted information. The purpose of this is to reduce the burden on dispatchers in abnormal situations and to prevent overspeed accidents due to omission of the operation notice.

6.4 Maintenance Work

We will develop a dedicated terminal for maintenance work. It will use radio communications to achieve functions such as track closing procedures and train approach alarms.

6.5 Passenger Information Service

Since this system has base terminals at locations between stations as needed and receives train position information from those terminals, it can allow the dispatcher’s office to acquire between-station line occupation information. It can also have information be displayed and announced at stations.

7 Future Schedule

We have carried out train test runs with the prototypes installed in the field. In these tests, basic functions have been checked between two stations and at one level crossing. Next we are planning to conduct monitor operation on trains in service before final introduction.

Reference: