We have carried out development of a network-based signal control system for automatic block signals for the purposes of reduction of signal cables, centralization and functional improvement of signal control for automatic block signals, and installation cost reduction. The system applies network-based signals to signaling facilities for automatic block signals and unifies signal control logic with an aim of improving availability and reliability of signaling devices, enhancing coordination of functions with each other, and enhancing remote monitoring control.

This time, we have developed a practical system for the network-based signal control system for automatic block signals and further improved transport stability and maintainability and ease of installation of the system. In this article, we will outline that development and introduce an overview of the field tests underway near Kita-Kogane station on the Joban rapid line.

**Keywords:** Network signal, Automatic block signals, Practical system, Maintainability, Ease of installation, Availability

### 1 Introduction

Block signals, track circuits, transponders of ATS-P and other signaling facilities are found between stations. They are separated by their individual functions and construct logic, mainly using relays, to send and receive conditions to and from each other (Fig. 1 (a)). This system structure is burdened by the following issues.

1. Simplex system (no back up system in case of equipment failure)
2. Huge amount of wiring work
3. Complicated relay circuit logic
4. Insufficient information obtaining about maintenance and failures from distant locations

In order to solve those issues, we are proceeding with a fundamental signal system improvement project on the Chuo and other lines. In that project, we solved the issues (3) and (4) by centralizing in the signal house control devices that were distributed along the tracks (Fig. 1 (b)). But, a huge number of signal cables have to be laid from the signal house to the individual devices, and those cables remain simplex. Thus, there is still room for improvement on the issues (1) and (2).

In light of that, we are proceeding with the development of a network-based signal control system for automatic block signals, aiming to reduce cable lying and wiring work and further improve facilities for automatic block signals (Fig. 1 (c)). For the network-based signal control system for automatic block signals, we are working to find solutions of the issues of signaling facilities for automatic block signals, including the above-mentioned (1) and (2), by connecting the logic controller in the signal house and field controller along the track with optical cables to reduce cables and make the system duplex.

Fig. 2 shows the development schedule of the network-based signal control system for automatic block signals. In the development of the prototype system which began at the beginning of FY 2005, we mainly developed the basic system structure and functions to be explained section 2, and we carried out field tests of the developed prototype near Kita-Kogane station on the Joban rapid line from August 2006. In those field tests, we extracted issues for enabling
practical use of the system. At the end of FY 2006, we started studying the specs of the system for practical use. In development of a practical system, we have carried out development with an aim of improving maintainability and ease of installation, and now we are making preparations to conclude on the final spec. The specific items in development of the practical system will be introduced in section 3.

2. Overview of the Network-based Signal Control System for Automatic Block Signals

Fig. 3 illustrates the system configuration of the network-based signal control system for automatic block signals. The system mainly consists of a logic controller (LC), field controllers (FC), an optical network and a remote monitoring control system. Devices are connected to each other by an optical network, and data transmission between devices is done by IP communication. Multiplexing of transmission between devices through a single transmission line significantly reduces the amount of cables required between the signal house and equipment along the tracks. The system including the optical cables has a duplex structure for reliability improvement.

2.1 LC
A LC is equipment that centralizes control logic of signaling devices for automatic block signals, and is located in the signal house of a station. It determines the specific control of each signaling facility based on the information from FCs and the interlocking device, and it sends the control instructions to FCs via the optical network. It is built in a duplex structure with fail-safe control devices.

Main functions of the LC are as follows.
(1) Identification of contact or drop of track circuits
(2) Determination of aspects of block signals, repeating signals and distant route indicators
(3) Processing of aspect activation information based on aspects of advance signals and onboard codes of ATS-P
(4) Determination of code information of ATS-P transponders

In the development of the practical system, we added the development of the block section extension function in case of track

circuit failures and the ATS-P on-line repairing function to improve transport stability and maintainability. We will explain those later.

2.2 FC
FCs are installed per block section. A FC transforms command data from the LC via the optical network into electric signals, and it controls signals, track circuits, ATS-Ps and ATS-Ss. They transform the information of train detection by track circuits and other operation status of equipment along the tracks into feedback data and transmit that to the LC via the optical network. Fig. 5 shows the box housing a FC, and Fig. 6 shows a FC block (half system of the duplex FC).

In a station yard network-based signal control system, FCs are installed for each signaling device (boxes are installed for some facilities) because the facilities are distributed along the tracks. But, in a network-based signal control system for automatic block signals, signaling devices are controlled as a set per block signal. In such a system, facilities to be controlled are concentrated around each block signal. They have a duplex structure with fail-safe control devices as LCs do.

Fig. 7 shows an image of the connection around a FC. A FC and signaling devices are connected by metallic cables with connectors. It uses non-insulated track circuit to detect a train, and a transmitter

Fig. 3 System Configuration of the Network-based Signal Control System for Automatic Block Signals
and a receiver for that are also built in the FC block.

There are three types of FCs according to their usage.

1. FCs that control block signals and other signaling facilities for automatic block signals (FCSG: FC for SiGnal)
2. FCs that have interfaces with the interlocking device and conventional ATS-P encoders (FCBO: FC for system BOundary)
3. FCs that indirectly control other station facilities with no interlocking devices (train approach indicators, block repeaters etc.) (FCIF: FC for InterFace)

2.3 Optical Network

LC, FCs and other devices are connected via optical cables to reduce the amount of cables. For the transmission method between LCs and FCs, we have adopted the PON (Passive Optical Network) method that is a universal technology used for FTTH (Fiber to the Home) because PON is good in terms of ease of installation and maintainability and is well suited for laying along the track on the following reasons.

1. With time-division multiplexing, PON can secure many lines to reduce the number of core wires.
2. Optical cables of PON can be multi-branched by using couplers without power supply.

FCs are arranged in series for automatic block signals (Fig. 3) and the main optical cable is optically branched at each box housing a FC (Fig. 7). The reception level of the signal in the optical cable might drop every time it goes through a FC in such a system structure, inhibiting transmission between distant FCs. Thus, we have chosen an asymmetric coupler as the optical coupler that can mitigate such signal level drop to secure a sufficient number of FCs connectable to
a single main optical cable. PON consists of an optical line terminal (OLT) and optical network unit (ONU). In our system, we set up a PON OLT in the signal house and house PON ONU in the FC boxes along the tracks. Furthermore, individual network devices (PON OLT, L2SW, L3SW) and optical cables are multiplexed. Fig. 8 shows a network device box that houses a PON OLT.

2.4 Remote Monitoring System

The remote monitoring system is a system to remotely obtain monitoring information from locations such as the dispatcher’s office, the technical center or the maintenance center in as much detail as in the signal house, and it enables resetting of devices for recovery from obstructions etc. at the dispatcher’s office. The remote monitoring system consists of remote monitoring servers (Fig. 9), remote servers and remote monitoring terminals (Fig. 10). Table 1 lists the functions of the remote monitoring server, remote control server and remote monitoring terminal.

Table 1 Functions by Component of the Remote Monitoring System

<table>
<thead>
<tr>
<th>Device</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote control server</td>
<td>• Remote control of LC and FCs (resetting etc.)</td>
</tr>
<tr>
<td>Remote monitoring server</td>
<td>• Monitoring operation of individual control devices and network</td>
</tr>
<tr>
<td></td>
<td>• Accumulating journals of individual control devices and network</td>
</tr>
<tr>
<td>Remote monitoring terminal</td>
<td>• Operating remote control server and remote monitoring server</td>
</tr>
<tr>
<td></td>
<td>• Indicating warnings and operation monitoring information from individual devices, obtaining and indicating of operation histories of those operations, operating remote control server and remote monitoring server</td>
</tr>
<tr>
<td></td>
<td>• Counting and plotting of max./min./ave. values of operation data of individual equipment along the tracks</td>
</tr>
</tbody>
</table>

Fig. 9 Remote Monitoring Server

Fig. 10 Remote Monitoring Terminal (left) and Remote Control Server (right)

Fig. 12 Example of Display of Remote Monitoring Terminal

In the development of the practical system, we have developed new hardware and functions based on the issues found in the prototype system development. An overview of that development is as follows.

3 Development of Practical System

In the development of the practical system, we have developed new hardware and functions based on the issues found in the prototype system development. An overview of that development is as follows.

3.1 Development of Hardware

3.1.1 Improvement of FC box

We downsized the FC box taking into account the limited installation space along the track. But, as a result, problems remained in ease of installation at setup and maintainability at parts replacement due to internal parts being too closely packed.

Thus, we have enlarged the size of the box slightly and improved the component arrangement. Specifically, we have improved the arrangement to enable operation check and replacement of individual components from the front side of the FC and wiring from the rear side for better ease of installation and maintainability. And we have further modified the component structure of the FC to allow replacement per internal unit.

Upon consideration of cases where a FC is installed on elevated sections and other places with heavy vibration, we have enhanced vibration isolation of the FC box. That lowers the vibration of the FC and other components to the specified level or less for vibration at 2G (double of the previous spec).
Fig. 5 shows the appearance of the improved FC box.

3.1.2 Development of the FCBO (FC for system BOundary)
In order to put this system into practical use, it has to have a serial interface with interlocking equipment and a transmission interface with ATS-P encoders, in addition to the relay interface, at the boundary with other systems. We have thus developed the FC for system BOundary (FCBO) that has those interfaces.

In the transmission between an ATS-P encoder, for example, the information required to control ATS-P over the system boundary is transmitted between the conventional ATS-P encoder and FCBO. The ATS-P encoder and the LC use that information to activate the aspects of the individual related signals.

3.1.3 Extension of the Controllable Distance of Facilities Along the Tracks
In the prototype system, we assumed that FCs would be located near block signals. But, in some actual situations such as in tunnels or on viaducts, FCs could be located far from the block signal due to limited space for installation.

We have thus enhanced the transmission power from the FC to the field signaling facilities to allow control even at the distance of up to 3 km.

3.2 Development of Functions
3.2.1 Improvement of the Anti-Noise Characteristics of Track Circuits
A FC detects a train with a non-insulated track circuit. The transmitter of the track circuit sends out a train detection signal to the rail and the receiver of that receives the response. When a train occupies a section between the transmitter and the receiver, the train detection signal response at the receiver becomes weaker because the axle short-circuits the rail. The FC accordingly determines that a train occupies that section.

The prototype system adopted the proven AM (Amplitude Modulation) method as the method for the train detection signal. On the other hand, we have decided to use the MSK (Minimum Shift Keying) modulation method for the practical system. In this system, two frequencies are alternately transmitted to the rail to clarify the distinction between the train noise and the train detection signal, thus improving the anti-noise characteristics in relation to trains.

3.2.2 ATS-P Online Maintenance Function
For reliability improvement, this system centralizes signal control logic for automatic block signals in the LC. But, in such a system architecture, system maintenance requires stopping control of all facilities for automatic block signals, causing the problem of a wide area being affected. Particularly, ATS-P code information sometimes affects facilities over a broad area even in the repair of a single signaling device, creating a need for system amendment. We thus had to take countermeasures for that.

Therefore, we have developed a method where the code information is updated while stopping only the ATS-P control logic when amending ATS-P code. When setting the ATS-P partial stopping mode at the LC, the LC stops output only related to ATS-P in the control information to FCs. While stopping that output, we stop half of the duplex LC system to amend the ATS-P code information.

3.2.3 Extension of the Block Section in Track Circuit Failures
When a track circuit for automatic block signals is damaged, we currently secure train operation by non-block operation with full attention. But that limits the number of train services, seriously affecting stable transport.

We have thus developed a function to extend a block section to continue train operation without non-block operation with full attention by specifying the faulty track circuit.

In the development of the practical system, we have developed the following basic functions for that.
(1) Function to control occupation of the section with faulty track circuit by checking the entry and exit of the sections in advance and rear of that section
(2) Function to set the function in (1), above, with from a remote monitoring terminal

3.3 Development of the Practical System in the Remote Monitoring System
3.3.1 Function of Identifying the Faulty Part in Device Failures
When a device failure occurs in conventional signal facilities, it sometimes takes long time to identify and restore the faulty part since there are many parts that could possibly fail. We have thus added a current detection sensor to the FC and improved the method of obtaining monitoring information. That allows us to identify the faulty part and indicate that on the display of the remote monitoring terminal in case of a device failure.

Fig. 13 shows an example of the display of the remote monitoring terminal that shows a failure of a track circuit.

3.3.2 Time Chart Display for Device Operation
Since most of the time-series journal of the device operation information is displayed as text in conventional signal facilities, it would take long time to find the required information. So, we have developed a function to display the time chart for device operation...
when conditions are selected in advance with the remote monitoring terminal, making it easier to find the required information at operation analysis and failure cause check.

Fig. 14 shows an example of the display of the time chart for the operation of a track circuit.

3.3.3 Portable Remote Monitoring Terminal

In the development of the prototype system, we assumed that the remote monitoring control terminal was to be set up indoors such as in the signal house or the dispatcher’s office. But, when a failure occurs outdoors such as near the FC, we cannot obtain failure and other information without the remote monitoring terminal there. Thus, in the development of the practical system, we have developed a portable remote monitoring terminal using a notebook PC to allow us to obtain detailed data of the signal facilities and the total system even on-site. That portable terminal is compatible with both wired and wireless connections.

4 Test of the Practical System

We have carried out stand-alone functional tests of each device, functional tests of combined devices, field tests and operation environment checks in testing of the network-based signal control system for automatic block signals. Here we will outline those tests.

4.1 Field Tests

We have set up the developed practical system between Mabashi and Kita-Kashiwa stations near Kita-Kogane station on the Joban rapid line for the field tests. In those test, we evaluate the control performance, the transmission performance and the reliability and environment resistance of the system in the long-term operation in the on-site environment. The tests started in June 2008 and we have been carrying those out, changing the test system configuration as development proceeding.

4.1.1 System Configuration

Fig. 15 illustrates the field test system configuration. The LC was installed in the former signal house of Kita-Kogane station. Six FCs (five FCSG and one FCIF) were installed in a total of five block sections: outbound No. 2 and No. 1 between Mabashi and Kita-Kogane and inbound No. 1, No. 2 and No. 3 between Kita-Kogane and Kita-Kashiwa. In order to input the aspect information of the entry signals with the existing interlocking device, we have installed two FCBOs as the interlocking equipment interface. The remote monitoring system is in the former signal house of Kita-Kogane station. We have built an optical network between those to control the FC and simulated signaling facilities for automatic block signals (block signals, repeating signals, track circuits, ATS-P, ATS-S and distant route indicators). In the field tests, we are making comparisons of the operation of that system to that of the existing system.
In order to verify the validity of the system in the actual train operation in the field tests, the system import the conditions of the existing facilities at relay contact points to compare the control details and control timing of the existing facilities and the network-based signaling system.

4.1.2 Evaluation
Evaluation items in the field tests are reliability and performance. The number of train runs in the field test section is approx. 200 a day each for inbound and outbound lines.

The evaluation criterion of reliability is whether or not any device failure occurs (if any, whether or not the cause and the countermeasure are specified). Failures occurred at some devices, but we found the causes and took countermeasures, after which the system has been operating normally. We have found no further failures and operation stops of field devices due to external environmental causes such as high temperature in summer and electromagnetic noise.

The evaluations of the functions are as follows, proving that the required performance is met.

(1) Non-insulated track circuit: We checked the position of the boundary between adjacent track circuits, short-circuit sensitivity, train detection and other performance items, and found that the specified train detection performance is met.

(2) ATS-P: We confirmed that functions such as control code encoding, onboard code reception and aspect activation are equal to the existing ATS-P.

(3) Signal aspect control, general purpose output etc.: We confirmed that those correspond to existing control. In some cases those did not correspond, but the cause was the difference of the train detection timing. That occurred because this system used electronic track circuits while the existing system uses relay track circuits. We proved that there were no problems with the logic processing of the LC.

(4) Transmission: We measured no errors of networking devices. Those devices are still operating with stability today.

(5) Remote monitoring server, remote monitoring terminal: We confirmed that those could detect device failures and output warnings.

4.2 Operating Environment Test
As electronic devices of the network-based signal control system are installed near the track, we have regarded device operating environment tests as an important issue from the beginning of the development, and we have studied measures to make devices stand up better to the environment. We are thus designing the FCs under a policy where the minimum environment condition values should be the values applicable to the conventional signaling facilities in the JIS standards. In the environment tests, we have measured different environmental data in field tests in addition to the functional tests in JIS standards. In the environment tests, we have measured different environmental data in field tests in addition to the functional tests in JIS standards.

In order to evaluate performance against high temperature in summer, we measured the temperature in the FC box. Fig. 16 shows part of the measurement results (August 7–17, 2008). The highest temperature in the FC box in the field test period was 52.6°C measured on August 8, 2008.

The FC box is a sealed structure, and the inner temperature is equalized with convection using a built-in fan. We confirmed that the inner temperature of the FC box meets the specification requirement of 60°C or less by using that fan.

On the other points too, we proved that the FC operates normally in the wayside environment.

5 Conclusion
We have introduced in this article the development of the network-based signal control system for automatic block signals, mainly through an overview of the improvement development and the field tests now underway.

Development of the practical system has been completed, and we have successfully made improvements and addition of functions that would be helpful to more stable transport and higher maintainability and ease of installation. We are now working to determine the final specifications.

For the future, we plan to further preparations to put the system into practical use in the greater Tokyo area.

Reference: