Radio-based Train Control System

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OVERVIEW: Railways must operate safely and in accordance with their timetables, and the signalling systems responsible for ensuring safety have been progressively improved in response to demand for greater safety, reliability, and efficiency. Drawing on technology built up through its experience with signals and safety systems such as electric interlocking devices and digital ATP equipment, Hitachi has collaborated with the East Japan Railway Company on the development of the ATACS radio-based train control system. ATACS is designed to meet user needs while delivering both safety and lower costs, including by minimizing the use of track circuits and wayside equipment, and by providing a comprehensive range of functions for dealing with abnormal situations.

INTRODUCTION

EVER since railways were first constructed, the signalling systems responsible for the safety of railway transportation have adopted methods that use signals equipment to achieve this, including track circuits, signals, and interlocks that control railway switches. In addition to improving safety, the wayside equipment has become complex and expensive as a result of introducing a wide range of practices such as the automation of railway management and improvements to transportation efficiency through increases in the number of train movements and measures such as allowing services to share the same railway track. This situation has led to demand from users for a reduction in costs while still maintaining the existing level of safety that has been built up over time. One way of achieving this that has been under investigation is to make further improvements in safety and to implement other measures such as cost savings by operating the control methods that in the past have primarily used wayside equipment in a way that integrates wayside and on-board equipment based on information and control technology.

To simplify systems that have become increasingly complex and to implement cost saving, a system has been devised that eliminates track circuits, which incur maintenance and other costs, and instead uses radio communications to transmit information on train position that to date has been sent via these track circuits. This is the advanced train administration and communications system (ATACS) train control system of the East Japan Railway Company, which is the first such system in Japan to use radio communications. The system can reduce maintenance and other life cycle costs by using radio communications to minimize wayside equipment. Reducing the number

TABLE 1. Development Stages of ATACS Train Control System

The ATACS train control system went through these development stages in preparation for practical implementation.

1995	East Japan Railway Company commences development of ATACS.
1997 to 1998	Monitor run testing performed on the Senseki Line for the phase 1 system (basic functions)
2000 to 2001	Monitor run testing performed for the phase 2 system (application functions)
2001	Development of prototype commences (improve reliability and durability).
2003 to 2005	Monitor run testing of prototype performed on the Senseki Line
2008	Development of commercial system commences (including addition of functions for dealing with abnormal situations required for actual use).
March 2010	Monitor run testing of commercial system commences.
October 10, 2011	Operation commences on Senseki Line (step 1).

ATACS: advanced train administration and communications system of these devices can also be expected to improve reliability. Because the system does not use track circuits, it can be used to implement moving blocks and to allow a higher density of railway traffic.

This article gives an overview of the ATACS train control system and describes its development.

DEVELOPMENT OF RADIO-BASED TRAIN CONTROL SYSTEM

Based on the Computer and Radio Aided Train Control System (CARAT) developed by the Railway Technical Research Institute from 1987, the ATACS system has been under development by the East Japan Railway Company since 1995 with the aim of practical implementation. Table 1 lists the different stages of the project. The ATACS system is divided into three parts: wayside equipment, on-board equipment, and radio equipment. Hitachi was assigned the task of developing the wayside equipment.

OVERVIEW OF ATACS

Pilot Track Section

The Senseki Line of the East Japan Railway Company was selected as the pilot track section for system development. The main reasons for this choice were as follows:

(1) Whereas most regional railway lines have an alternating current (AC) power system, the Senseki Line operates on direct current (DC) and it does not share track with adjacent lines such as the Tohoku Line.

(2) The line includes underground as well as open railway track.

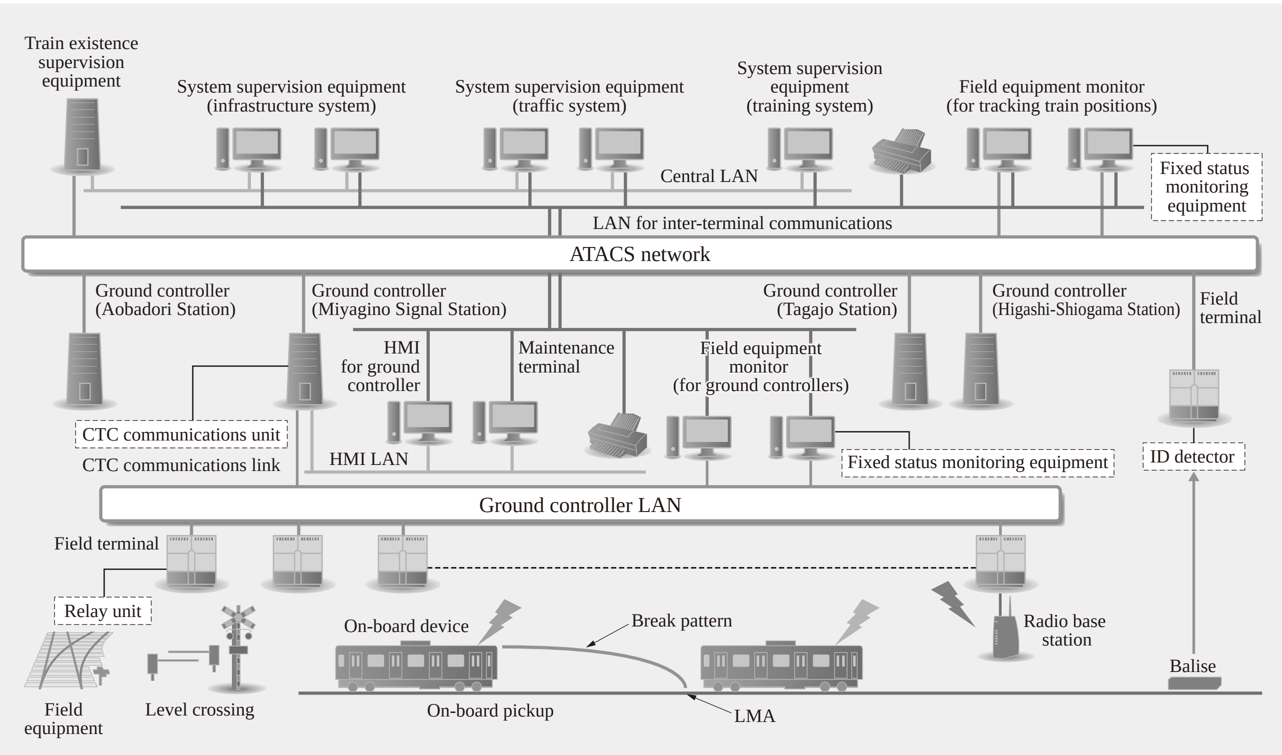
(3) The trainset configurations are comparatively simple.

(4) Because it runs through the commuter belt of

TABLE 2. System Specifications

The ATACS train control system for the Senseki Line of the East Japan Railway Company divides the approximately 18 km of track into four segments.

Line being controlled	Senseki Line (approximately 18 km between Aobadori and Higashi-Shiogama Stations)
No. of ground controllers	4
No. of radio base stations	8
Distance between base stations	Approximately 3 km
No. of trains	16 trains/ground controller
Radio frequency	400-MHz band



LAN: local area network CTC: centralized traffic control HMI: human-machine interface LMA: limit of movement authority

Fig. 1—Block Diagram of ATACS System for Senseki Line.
The wayside equipment used for train control by the Senseki Line system includes four ground controllers responsible for separate sections of track, and the train existence supervision equipment that acts as a central controller.

Sendai city, the Senseki Line has a reasonably high frequency of service.

It was chosen with a view to future deployments on railway lines in Tokyo and elsewhere.

Overview of ATACS System for Senseki Line

The ATACS installed on the Senseki Line covers approximately 18 km of track between Aobadori and Higashi-Shiogama Stations (the full line runs from Aobadori to Ishinomaki Station). It has four ground controllers, uses digital radio operating in the 400-MHz band, has eight radio base stations, and controls a total of 18 trainsets (see Table 2).

Fig. 1 shows a block diagram of the system configuration.

The wayside equipment includes ground controllers, field controllers, train existence supervision equipment, system supervision equipment, and human-machine interfaces (HMIs) for the ground controllers.

(1) Ground controllers

The ground controllers are installed at stations where interlocks are used. Based on electric interlocking devices (which are used for signalling and safety), they are computers with three-way redundancy and are used to perform interlock control as well as radio-based train control functions such as train interval control and tracking. They integrate ATACS and interlock control functions into a single system (alternatively, the interlock function can be split off, in which case they are configured to work with separate interlocking devices), and can also interconnect with the centralized traffic control (CTC) station equipment installed on local railway lines. In addition to using encryption for data sent via radio (implemented in the radio units), the controllers also have features for dealing with radio interference and for detecting falsified radio signals.

The functions of the field controllers include control of field equipment such as the railway switches installed at stations and also communications with the radio base stations. These field controllers connect to the ground controllers via the ground controller local area network (LAN), which uses optical fiber and has double redundancy (see Fig. 2).

(2) Train existence supervision equipment

The train existence supervision equipment tracks and supervises all of the trains controlled by the system. They include backup functions in the event of ground controllers shutting down, an identifier (ID) shift function in the event of faults or other abnormal

Fig. 2—Ground Controllers.
The functions of the ground controllers include controlling the intervals between trains and calculating LMAs.

Fig. 3—Train Existence Supervision Equipment.
The train existence supervision equipment tracks and supervises all of the trains controlled by the system, and provides backup functions in the event of a problem in the ground controllers.

circumstances on trains, and a function for setting temporary speed restrictions. The equipment connects to the ground controllers and exchanges data via the ATACS network, which uses optical fiber and has double redundancy (see Fig. 3).

(3) System supervision equipment

The system supervision equipment provides the user interface functions for the train existence supervision equipment, including monitoring of traffic and the interlocking devices at each ground controller site.

The HMI for the ground controllers provides interlock control panel functions at each site. It can also be used to operate the interlocking devices from stations if a problem occurs in the central CTC equipment (see Fig. 4).

(4) Radio equipment

The radio equipment consists of the radio base stations and the on-board radio units on the trains. The radio base stations are located at approximately 3-km intervals and perform bidirectional communications with the on-board radio units using antennas for space wave transmission on above-ground sections of track and leaky coaxial cable (LCX) for tunnels and underground sections. The following are some typical examples of data sent via radio.

(a) Data sent from wayside equipment to the on-board equipment

(i) Limit of movement authorities (LMAs)

(ii) Route information

(iii) Obstacle information

(iv) Temporary speed restrictions

(b) Data sent from the on-board equipment to wayside equipment

(i) Train information (train position, train number, etc.)

(ii) Direction of travel

(iii) Level crossing control commands

(5) On-board devices

The on-board devices are located in the driver's compartment of each trainset. In addition to calculating dynamic speed profiles based on the LMAs sent from the wayside equipment and displaying speed limits in the driver's compartment, they also trigger braking if the train exceeds its speed limit.

Overview of Radio-based Train Control

Instead of using signal indication as in the past, ATACS control of a train involves the ground controller using radio to transmit an LMA (which specifies the position to which the train can safely advance) to the on-board equipment. The on-board equipment then uses the received LMA to generate the optimal dynamic speed profile based on the performance capabilities of the train. Although the actual driving of the train is still performed by the train driver, the system is designed to apply the brake automatically if the train exceeds the speed specified in the dynamic speed profile. While the basic approach to train control is the same as digital automatic train protection (ATP), because there are no track circuits (blocks), moving blocks are implemented by controlling the interval between trains.

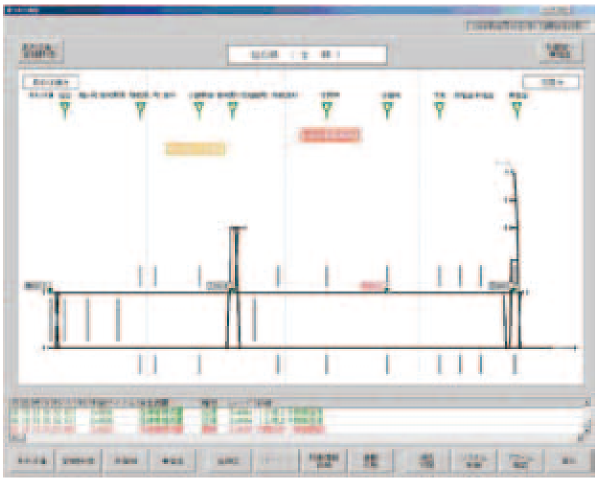


Fig. 4—System Supervision Equipment (Example Traffic Display Screen).
The screen shows the location of trains and LMAs in the system.

The following gives an overview of this method of train control.

(1) Using the track database, tachometer generator, and positioning correction balises, the on-board equipment determines the position of the train.

(2) This information is then transmitted by radio to the wayside equipment.

(3) The wayside equipment determines the LMA for each train based on factors such as the received position information and the status of route control, and transmits this information to each train by radio.

(4) The on-board equipment uses the received LMA to generate the dynamic speed profile and performs any braking control if needed.

This describes how control is performed under normal circumstances.

The following are some examples of the functions for handling abnormal circumstances.

(1) Function for sending emergency stop commands

This function sends an emergency stop command to affected nearby trains if a problem occurs on a train, such as an interruption to the system's radio communications.

(2) Backup function in case of fault in radio base station

This function maintains control operation in the event of detecting a failed radio base station by disconnecting the faulty base station and using adjacent base stations as backup for its coverage area (see Fig. 5).

(3) ID shift function

If a train has a fault such as an interruption to radio communications, this function tracks the train instead by using an on-board ID device on the train.

(4) Function for detecting rolling stock without ATACS device

This function detects any rolling stock without an ATACS device that enters the railway track controlled by the system and responds in ways that include issuing stop commands to any nearby rolling stock that is fitted with an ATACS device.

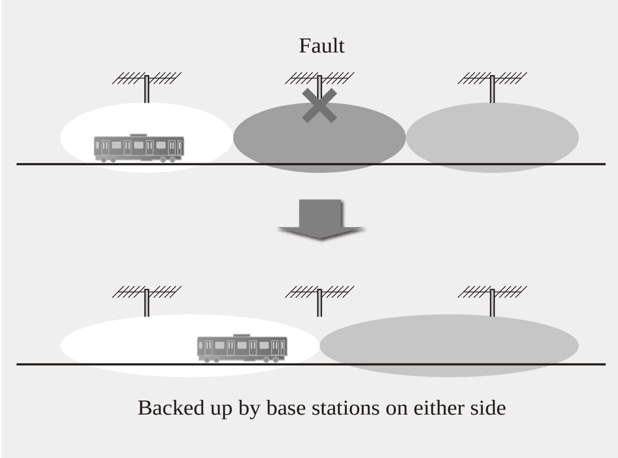


Fig. 5—Backup Function in Case of Fault in Radio Base Station.
Train service can continue to operate in the event of a radio base station developing a fault, because the adjacent base stations provide backup for its coverage area.

Level Crossing Control Function

The conventional method for controlling level crossings involves using track circuits or level crossing controllers located on the wayside to detect a train and to turn the warning on or off accordingly. The timing for turning on a level crossing warning is determined based on the maximum train speed, which means that the warning remains on for a longer time for slower trains. With ATACS, on the other hand, because trains know their own position and speed at all times and therefore can determine how long it will take them to arrive at a level crossing, it is possible for the trains themselves to issue level crossing warning commands to the wayside equipment.

Using radio in this way makes it possible to perform train-based control of level crossings based on factors such as train speed and type, and to determine an appropriate length of time for the warning to remain turned on.

Monitor Run and Control Run for Senseki Line

Day and night monitor run testing commenced in March 2010 to perform final checks, followed in April 2010 by nighttime control run testing.

Monitor run testing involves running ATACS in parallel with the existing automatic train stop (ATS) system (with output of braking by ATACS disabled). This form of long-run testing was performed to confirm that the operation of trains on the Senseki Line was consistent with the system, and to verify radio conditions throughout the year given the potential for seasonal, meteorological, and other influences.

Control run testing involved switching actual operation over to ATACS to check radio-based train control, the operation of various functions, and connections to field equipment under actual train operation.

The data produced by these tests were analyzed to confirm that there were no problems.

CONCLUSIONS

This article has given an overview of the ATACS train control system and described its development.

The ATACS for the Senseki Line will commence operation for both the step 1 and step 2 stages. Step 1 involves commissioning the basic radio-based train control functions and step 2 involves a plan for train-based control of level crossings.

The East Japan Railway Company has already started work on plans to introduce ATACS in the Tokyo metropolitan area in the future. There is also strong demand from other railway operators to eliminate track circuits, and the system has attracted attention for its potential to reduce maintenance costs.

Outside Japan, radio-based train control systems are becoming progressively more mainstream. Because ATACS corresponds to the European Train Control System (ETCS) Level 3, there is a prospect of expanding its market overseas as well as in Japan.

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