Latest Signaling Systems for Train Control and Future Trends

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OVERVIEW: Providing safe and secure transport is the most basic principle of railroads, and this is made possible by train control systems. Drawing on its expertise in information control technologies, Hitachi has made enormous strides in addressing user needs by developing digital ATC (automatic train control) systems for application to congested rail lines, reducing train headways, improving passenger comfort with one-step brake control, reducing the amount of track-side equipment, and many other initiatives. However, these innovations are not just confined to congested routes, for every line can benefit from improved safety and lower costs for track-side equipment and maintenance. To meet these needs, it is essential to achieve closer cooperation between track-side and on-board systems than in the past, and to develop train control systems with the flexibility to run autonomously. Leveraging its expertise and technological edge, Hitachi is moving boldly to develop new systems and a wide range of solutions calculated to enhance rail services in the near-term future.

INTRODUCTION

AMONG the many different kinds of railway systems, the train control system occupies a critically important role: guaranteeing the safe and secure operation of the train. Railroad companies today are faced with a host of issues—the declining birthrate and increasing proportion of elderly in the population, increasingly diversified needs of users, the prevailing harsh business environment of railroads—and train control systems too are faced with difficult challenges:

(1) providing safe, secure transport,
(2) lower equipment costs,
(3) greater flexibility in meeting transport requirements, and
(4) supporting more efficient maintenance operations with fewer signal technicians.

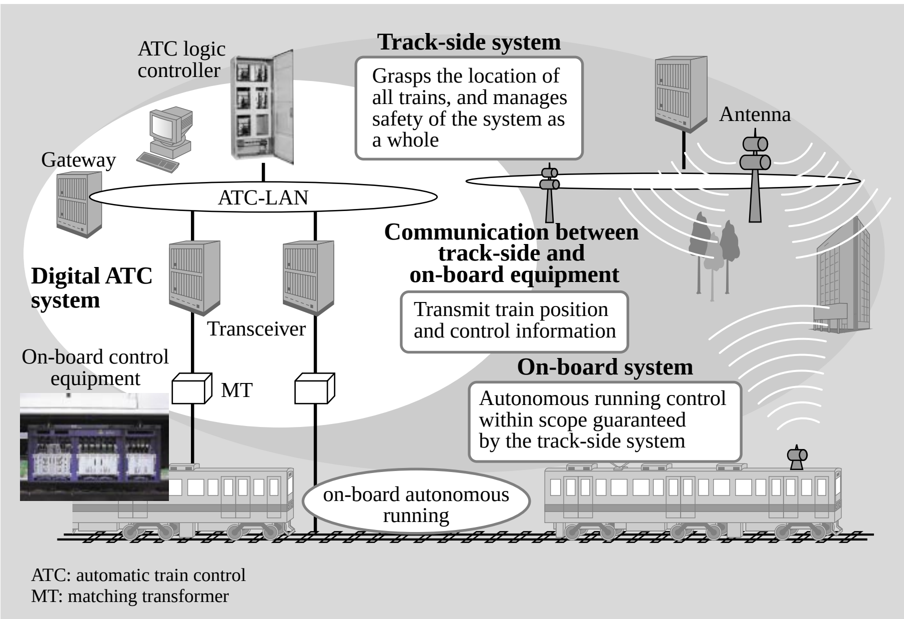

Fig. 1—Overview of Hitachi's Train Control System.
Hitachi is a leading developer of new solutions and advanced train control systems such as the digital ATC system that achieves unprecedented flexibility through seamless interconnection between track-side and on-board systems.

As a comprehensive railway system integrator, Hitachi emerged as a major player in the development of train control systems making good use of the company's expertise in electronics and digital software starting with a computerized interlocking system in the 1990s. This article will focus on Hitachi's digital ATC (automatic train control) system and future train control system trends as a fundamental solution to the challenges and needs of today and the years ahead.

DIGITAL ATC SYSTEM

Record of Deployments

Hitachi's digital ATC system is already in service on a number of train lines, and has continued to perform flawlessly up to the present:

(1) Tohoku Shinkansen (bullet train) Line (from Morioka to Hachinohe) installed December 2002

(2) Keihin-Tohoku Line (from Minami-urawa to Tsurumi) installed December 2003

(3) Tokyo Metropolitan Bureau of Transportation Shinjuku Line (from Shinjuku to Motoyawata) installed May 2005

The digital ATC system is already scheduled for installation on the Tohoku and Joetsu Shinkansen Lines and on the Yamate-Negishi Line, and will be put into service on a growing number of lines over the next few years.

Digital ATC System Overview

In the conventional analog ATC system, speed information is carried by different frequencies of an analog signal that flows in the rails and a multi-step brake system imposes uniform speed control for each line. Now the requirement for more precise train spacing control has emerged as a way of improving operating efficiency, reducing arrival times, and helping achieve other modern transport needs.

The digital ATC system works very differently. In the digital system, the track-side equipment detects train occupancy through a track circuit, generates stopping point information based on the position of the train ahead, and this stopping point information is transmitted via rails as a digital ATC signal to the on-board equipment. Meanwhile, the on-board equipment stores route data and various train performance data in an on-board database. When the train receives information from the track-side equipment, the on-board system acts on the information autonomously based on information in its own database, and applies the optimum one-step brake control (see Fig. 2).

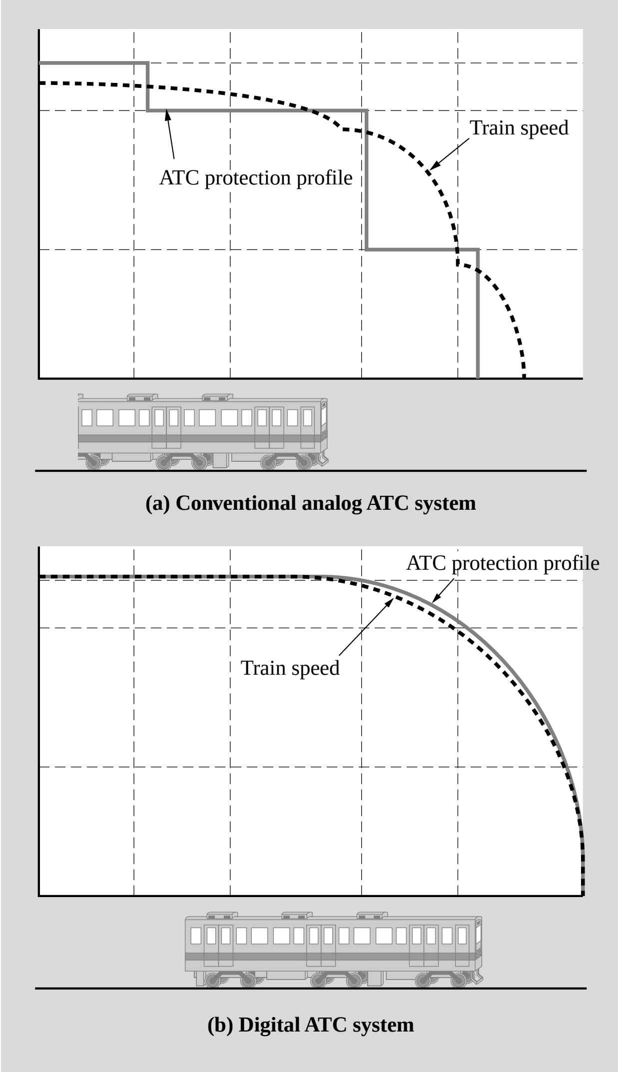

Fig. 2—Comparison of Analog ATC System and Digital ATC System Control Schemes.
The digital ATC system employs one-step brake control based on stopping point information received from the track-side system and is able to stop within a shorter distance and shorter time interval than the conventional analog ATC system even when running at the same speed.

Effects of Digital ATC System Introduction

The new digital ATC system offers a number of significant improvements over the conventional analog ATC system:

(1) Reduced train headways and required travel times

With the digital system, the inherent losses associated with the conventional analog system are eliminated, thereby reducing the running distance between trains and required times. Even when trains are made up of cars having varying performance, the system derives the full performance from each car.

(2) Precise train spacing control

Digital ATC supports far greater data capacity between track-side and on-board equipment than the analog ATC, and this permits all kinds of useful information to be transmitted that could not be sent before including train protection information and preceding train information. Making this information available in the cab permits much more precise train spacing control.

(3) Improved passenger comfort

One-step brake control based on the speed check profile in the on-board database enables a smoother, more comfortable ride.

(4) Costs reduced and availability improved by simpler track-side equipment

Substantial reduction in the number of equipment units has simplified systems as a whole and helps reduce costs. In addition, redundant systems can be easily implemented, which contributes enormously to reduce the failure rate and improve availability.

Digitizing ATC Functions

Fig. 3 shows a schematic overview of the digital ATC system. The ATC logic controller and transceiver are connected by a network, and ATC signals and train detection signals are transmitted as messages. The transmitter uses a DSP (digital signal processor) to convert (digitally modulate) the messages to ATC signals and train detection signals, which are then transmitted by the track circuit. The DSP in the receiver demodulates the incoming train detection signal from the track circuit, and sends the received message to the ATC logic controller via the network.

Of course there is always the potential for transmission errors when sending information over a network, or signal processing errors when using a DSP. However, the communication scheme and device configuration have been carefully implemented to prevent train control abnormalities, train detection abnormalities, or other potential risk factors.

Train Control Safety

The ATC signal carrying the train control information is generated by the ATC controller which is a fail-safe device. If an abnormality occurs in the ATC logic controller, it is designed to ensure that the transmission of ATC signals is suspended. And if the track circuit loses the ATC signal, the on-board equipment automatically applies the brakes and brings the train to a halt to ensure safety. Moreover, when the ATC signal is sent from the ATC logic controller over

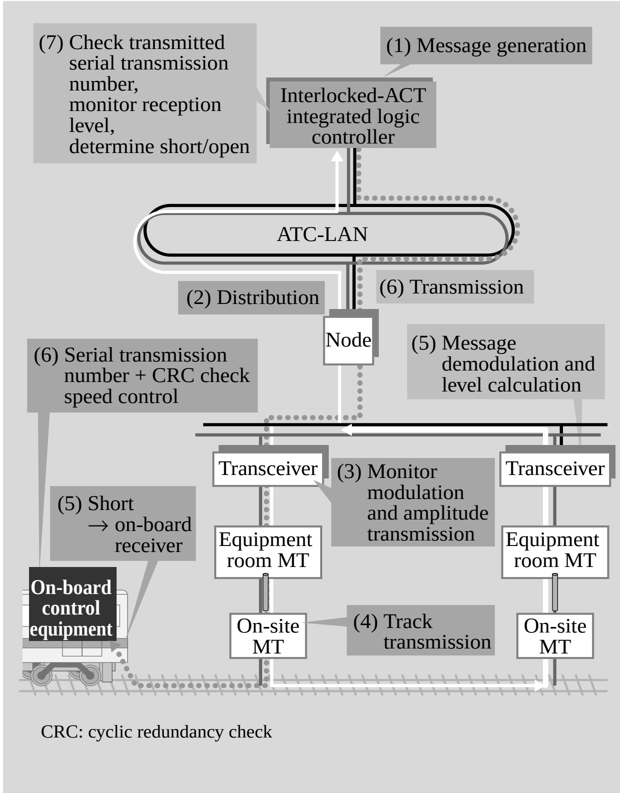

Fig. 3—Digital ATC System Configuration and Message Flow.
ATC messages generated by the logic controller are sent over the network to the transceiver, where they are digitally modulated and sent to the track circuit. Train detection messages are demodulated by the receiver, and the logic controller detects whether short or open.

the network, the message is checked by the on-board equipment to make sure that the content is valid, and the following information is added to the signal to ensure its safety:

(1) Serial transmission number: by checking serial transmission number updates, one can verify that a permanent failure has not occurred on the transmission line.

(2) Destination: the track circuit number to which the signal is sent is attached to the ATC signal. The on-board equipment checks this information and the train's own position to ensure that the ATC message was not received from the wrong transmitter.

(3) CRC (cyclic redundancy check): A CRC function in incorporated in user data, and fail-safe on-board equipment checks the CRC function to ensure that a transmission error has not occurred on the network or the track circuit.

In the event that an error is detected by any of the above checks, the ATC message is destroyed, the train controls are put on hold, and if a valid ATC message is not received within a fixed period of time, the train is automatically stopped to ensure safety.

FUTURE TRAIN CONTROL SYSTEM TRENDS

Train Control Systems for Increasing Train Intelligence

The on-board digital ATC system capabilities described are certain to become much more advanced and intelligent than the train control systems that we have had up to now. Further development of digital processing technology will enable more sophisticated functions and smarter on-board systems.

Fig. 4 shows a schematic overview of a train control system that can accommodate more intelligent on-board systems. The track-side system manages all the information coming from the on-board system (location information, etc.), and transmits whatever information is needed for safe running to all the trains in the vicinity (stopping positions, speed limits, etc.). In other words, the system consists of three elements:
(1) the track-side system manages overall safety,
(2) the on-board system exercises autonomous running control within the scope guaranteed by the track-side system, and
(3) continuous communication is supported between the track-side and on-board systems.

Communication between the track-side and on-board systems will use a number of different media including rail-based transmission such as the digital ATC signal, LCX (leaky coaxial) cable, and space wave and other wireless transmission schemes.

Autonomous Running by On-board Systems

Trains are able to run autonomously and safely based on their own on-board systems using route data that is stored in the train's on-board database. Specifically, the on-board system detects and manages the train's own position vis-à-vis the stopping position that is sent from the track-side system. The on-board system generates its own speed check profile permitting safe running by means of sequential computation based on the route data—current position, curves, inclines, branch restrictions—and controls the speed of the train accordingly. Essentially, this means that each train can run flexibly in accordance with its own autonomous and line transport requirements within the scope guaranteed by the track-side system. Moreover, with increasing track-side-on-board transmission capacity and more advanced functionality of on-board equipment, this will permit more extensive operating support information for crew members. And at the same time on-board equipment becomes more intelligent, the dependence of conventional train control systems on wayside signals, beacons, ground coils, and other track-side equipment will diminish, and this will reduce the volume and the cost of these track-side facilities. This should also improve the flexibility and expandability of the system as a whole.

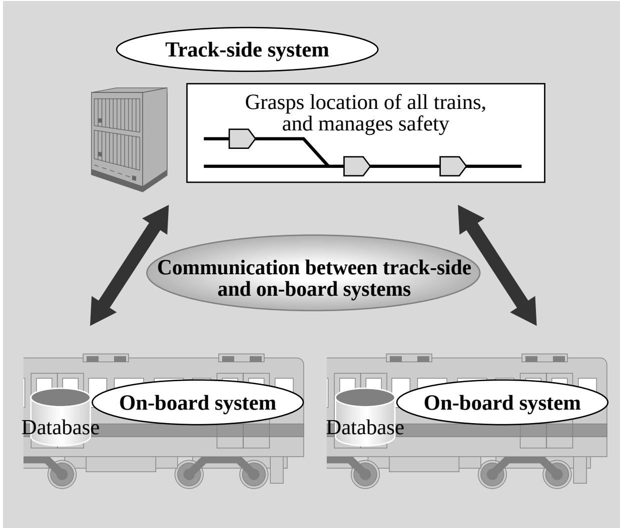

Fig. 4—Basic System Configuration for Increasing On-board Intelligence.
Consists of three elements: track-side systems, on-board systems, and communication between track-side and on-board systems.

Global Trends in Train Control Systems

The trend described above toward more intelligent on-board systems can be observed in other countries as well and is driving such initiatives as the ETCS (European train control system) and the CBTC (communications-based train control) system. These developments are similar in that stopping point data and other control information are continuously transmitted from the track-side system to the on-board equipment over a wireless connection, and most of the train control decisions are made autonomously by the on-board system.

In Japan, the East Japan Railway Company is now conducting field trials of the ATACS (advanced train administration and communication system), a wireless-based on-board control system.

CONCLUSIONS

This article provided an overview of Hitachi's digital ATC system and highlighted some future trends in train control systems. By leveraging its expertise in IT, Hitachi will continue to push ahead with development of modern train control systems based on seamless cooperation between track-side and on-board systems, and remain fully engaged in global developments as well.

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