SAINT Integrated Signaling System with High Reliability and Safety

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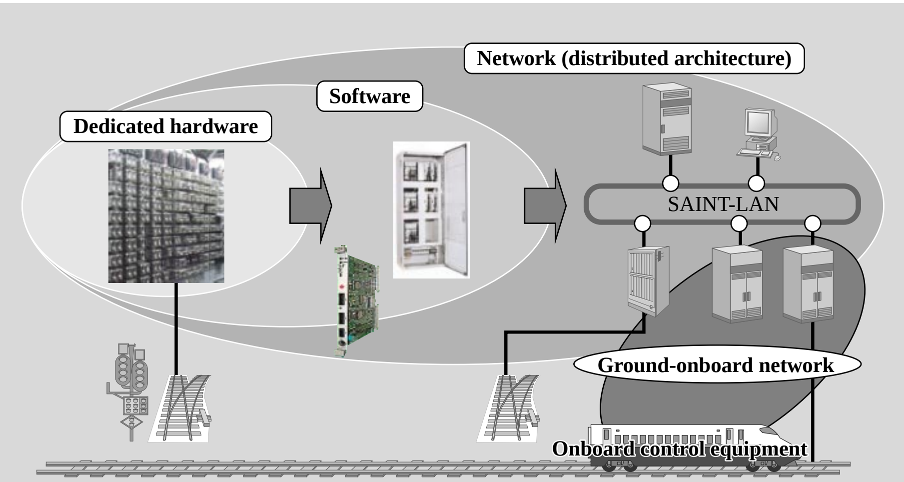
OVERVIEW: Trains could not run safely without signaling systems. Hitachi, Ltd. has been an industry leader in the development of general-purpose computerized interlocking systems, digital ATP systems, and other innovative products supporting railway signaling systems that provide the highest standard of safety and reliability. Recent initiative has focused on the development of an integrated signaling system called SAINT that combines previously separate interlocking and ATP systems to achieve greater efficiency, space savings, and cost efficiency. Implemented for the first time by leveraging all the company's previous technology and expertise, SAINT represents the culmination Shinkansen signaling system. Never content to rest on its laurels, Hitachi is committed to day-to-day progress in developing new technologies to meet the needs of railway operating companies and to contribute to society at large.

INTRODUCTION

SIGNALING equipment is indispensable to the operation of railways to prevent collisions, derailing, and to support the safe and efficient operation of trains. Ensuring safety is the primary purpose of these systems that adopt a fail-safe configuration so they error on the side of safety no matter what sort of accident or event might occur. Hitachi has always been in the forefront of innovative efforts to develop interlocking systems and ATP (automatic train protection) systems, core signaling systems. Meanwhile, the need for advanced signaling systems by the railway operating companies remains as high as ever before (1) to improve safety and reliability, (2) to flexibly accommodate transportation demand, (3) to reduce equipment costs, and (4) to promote more efficient maintenance operations even as the number of signalmen and other crew members is reduced. This paper describes the development of SAINT (Shinkansen ATP and interlocking system) shown schematically in Fig. 1, in response to the needs and requirements of railway operators. SAINT is a



SAINT-LAN: Shinkansen ATP and interlocking system–local area network
ATP: automatic train protection

Fig. 1—Evolution of Signaling Technology and Integrated Signaling System SAINT.
A leader in innovative signaling technologies, Hitachi developed a general-purpose computerized interlocking system, a digital ATP system, and continues to bring out a steady stream of advanced signaling products and solutions.

powerful new signaling system combining interlocking and ATP, that were previously implemented as separate systems.

GENERAL-PURPOSE COMPUTERIZED INTERLOCKING SYSTEM

An interlocking system is an arrangement of signals, switches, and other apparatus enabling a safe configuration of routes that prevents conflicting movements through an arrangement of tracks such as junctions and crossings. Earlier mechanical interlockings were superceded in the 1950s by relay interlocking devices built around control logic using solenoid relays with asymmetric fault characteristic to ensure fail-safe system operation. Then in the 1980s, Hitachi began work on a computerized interlocking system based on general-purpose computers, and the new computerized interlocking system was first deployed in 1993. The system uses general computers to implement a redundant configuration of fail-safe processors, and the standard control logic (logic control by built-in interlocking table) and station-specific control data are separated and implemented in software. This not only provides the same high standard of safety as the previous relay interlocking, but also supports improved functionality and maintainability.

DIGITAL ATC SYSTEM

ATP ensures safe and smooth operation of trains by controlling the speed and distance between trains. Track circuits detect the train's location and send permitted speed signals to equipment on board the train based on the train's occupancy status in a specific block. The conventional analog ATP system was based largely on analog technology. It derived the permitted speed from track circuits using solenoid relay-based train detection and control logic the same as the earlier relay interlocking system, then allocated the permitted speed information to certain frequency signals for transmission to the onboard equipment. This system was implemented using dedicated hardware, which resulted in massive and heavy equipment and made it extremely difficult to accommodate more advanced capabilities and functions. These drawbacks led Hitachi to begin work on a digital ATP system in the 1990s based on information processing and network technologies, and the new digital system was put into service on the Tohoku Shinkansen Line (between Morioka and Hachinohe) in December 2002. Here we will consider the digital ATP system in greater detail.

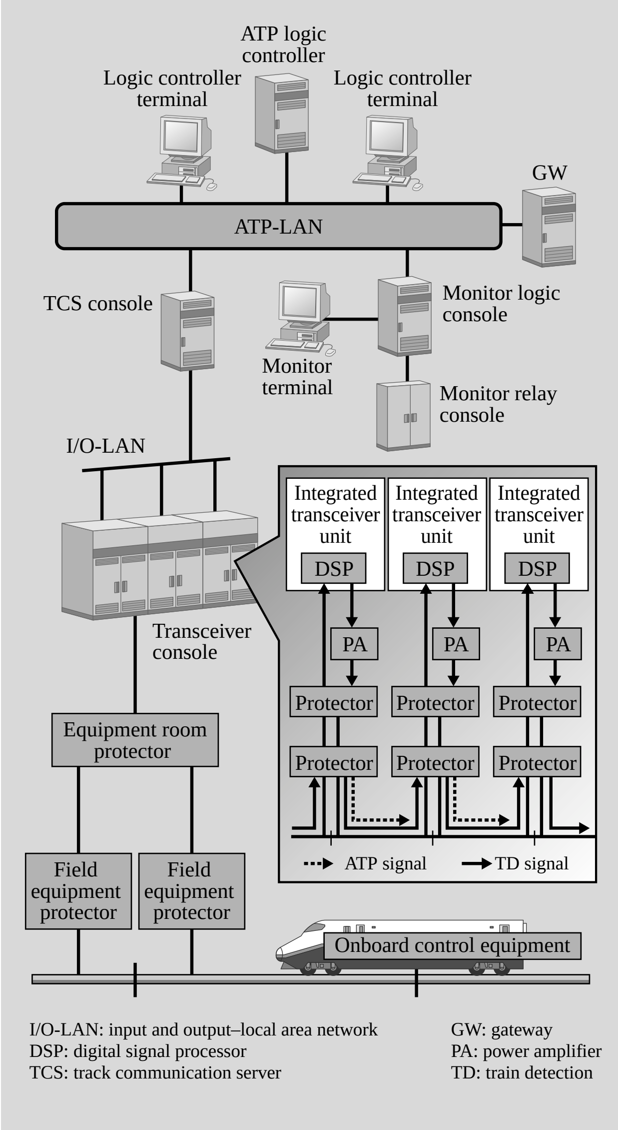


Fig. 2—Digital ATP System Configuration.
Train detection and the stopping point calculation function that were previously implemented in hardware are now implemented in software in the ATP logic controller and transceiver unit.

Digital ATP System Configuration

In digital ATP, stopping point and speed limiting information is sent from the ground equipment to the onboard control equipment, where it is compared with braking profile and line data stored in the train's onboard memory to control the speed of the train. Fig. 2 shows a schematic overview of the digital ATP system. In the conventional analog ATP system, the train position detection is implemented in hardware, and the train stopping point calculation functionality is implemented in software in the ATP logic controller and onboard transceiver unit. TD (train detection) and

ATP messages for train detection are sent to the transceiver which consists of a DSP (digital signal processor) via ATP-LAN (local area network), TCS (track communication server), and I/O (input and output)-LAN. The TD and ATP messages are digitally encoded by the DSP using MSK (minimum shift keying), and transmitted to the track circuits. TD signals received from track circuits are demodulated and processed by the transceiver DSP. Since multiple TD signals and ATP signals can be processed by the DSP, the transceiver unit of the digital ATP system can be dramatically reduced in size.

Fig. 3—DSP/PA Transceiver Unit.
Integrating the DSP and PA saved space by increasing the implementation density of the transceiver unit.

Technological Advantages

(1) Network-based configuration

By going over to a system where the ATP logic controller is connected to the transceiver unit over the network, we could achieve a remarkable transformation from conventional analog technology to a new configuration based on the transmission and processing of digital data, enabling better reliability and more compact implementation of hardware. And by adopting fail-safe designs for both the data processing equipment and the transmission pathway between the equipment, the result is a fail-safe configuration for the system as a whole which is implemented as a distributed system with various equipment (functions) connected over the network. This arrangement ensures the independence of the various equipment units (functions), and greatly improves the maintainability and scalability of the system. It also makes it easier to upgrade the system because places along the line to be upgraded can be localized, so the system can be built up in stages.

(2) Leveraging DSP in the transceiver unit

Conventional analog ATP uses different frequencies to carry TD signals and ATP signals, so this requires separate transceiver units. By contrast the digital ATP system processes only digital signals, so we developed a new ATP transceiver built around DSPs to process the signals. This new ATP transceiver can process up to 10 channels of the frequency band used for ATP at the same time, as well as filter and monitor TD and ATP messages. By implementing an ATP transceiver that can process both TD and ATP signals, we were able to dramatically reduce the size of the equipment. We also implemented the transceiver and PA (power amplifier) on one compact board, which further reduced the footprint of the equipment and improved the equipment console density. Fig. 3 shows a photograph of the DSP/PA transceiver unit.

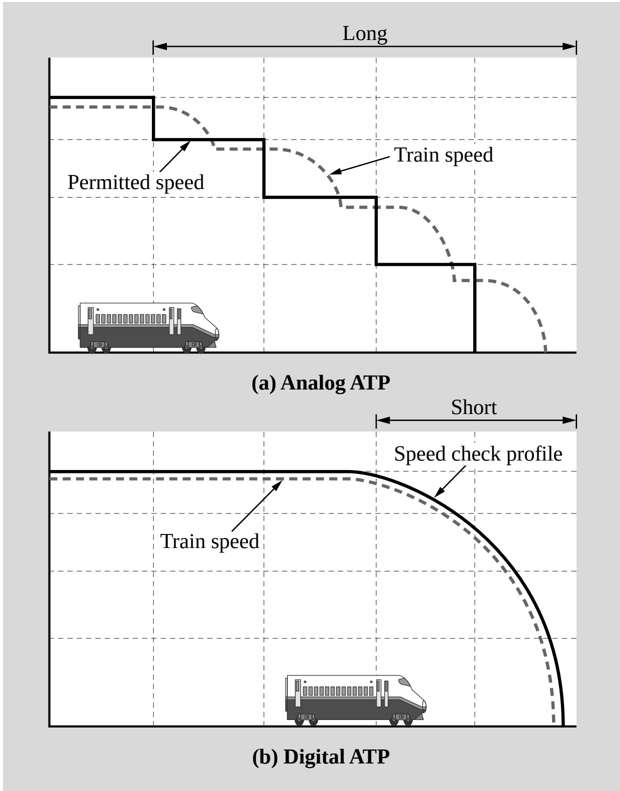


Fig. 4—Comparison of Analog and Digital ATP Control Methods.
Digital ATP uses a single-step braking profile based on stopping point information received from the ground equipment. The train is able to stop within a shorter distance compared with trains controlled by analog ATP traveling at the same speed, for shortened train headway.

(3) Onboard autonomous control

The signal sent to the track circuit in the conventional analog ATP system is a frequency-modulated permitted speed signal, but of course the signal in the digital ATP system is digital and is therefore capable of transmitting vastly more information to the onboard equipment. Train control has also been markedly improved as illustrated in Fig. 4 by switching over from the old track-circuit-unit (block) method of speed control to stopping-point-target control for each train by storing line and train performance data in onboard memory, and train control has been further optimized by rethinking the allocation of functions between ground equipment and onboard equipment.

(4) Assurance

Note that both ATP systems are supported on the same lines, and switching from one system to the other is easily accomplished by sending an ATP switching message. This permits smooth transitioning back and forth between the digital and the analog ATP systems, and allows upgrade work to proceed smoothly in stages.

INTEGRATED INTERLOCKING AND ATC SYSTEM "SAINT"

Interlocking and ATP Integration

Up to this point we have treated the interlocking equipment and ATP system separately, because the control objectives of the systems are different and they have always been implemented in separate hardware logic. But building on our cumulative expertise in computer, software, hardware, and new fail-safe technologies, we made a significant breakthrough in the development of SAINT, that better optimizes and fully integrates both interlocking and ATP systems as illustrated in Fig. 5. We were able to eliminate the functional redundancy of having two systems by integrating the application software, and the responsiveness of the system was significantly improved by adopting a shared scheduling table and optimizing the input/output sequencing of various functions. Another key feature of SAINT is that this is the first system not equipped with a solenoid relay in the Shinkansen line, thus making it possible to develop electronic terminals that can directly control field devices. The electronic terminals have been implemented as a fully relayless redundant configuration, and considering the higher breakdown voltage standard of Shinkansen compared with other lines, we improved the breakdown voltage performance based on a thorough reassessment of the control boards. The SAINT was put into service on the Tohoku Shinkansen between Tokyo and Morioka, and is working flawlessly as designed. Plans are underway to deploy the system next on the Joetsu Shinkansen.

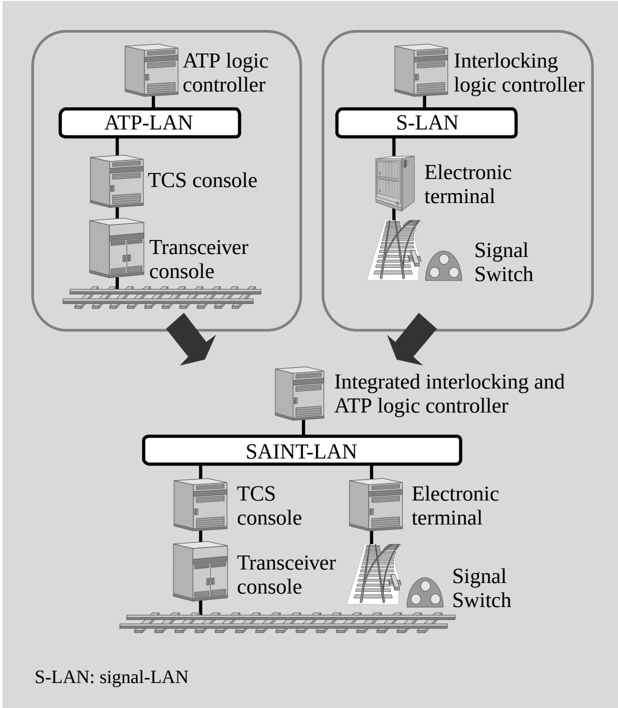


Fig. 5—Integrated Interlocking and ATP.
Enhanced reliability and space savings are achieved by integrating the ATP logic controller and interlocking logic controller in the same hardware unit.

Advantages of SAINT Deployment

Deployment of the SAINT system combining interlocking and ATP capabilities has significant advantages for meeting the needs of railway operating companies.

(1) Shorter train headways and travel times

Use of single-step break control based on stopping point information eliminates idle running time delays associated with conventional multi-step ATP brake control, it permits mixed operation of different kinds of trains (express, local, and freight trains) on the same track at optimum speed, and it reduces train headways and travel times.

(2) Improved riding comfort and train operability

Smoother deceleration along the single-step braking pattern coupled with feedback control based on transitional braking results in substantially better riding comfort and train operability.

(3) Simpler more cost-effective ground equipment with smaller footprint

Ground equipment is implemented more compactly using general-purpose data equipment and using software instead of hardware, and the equipment is implemented more efficiently by integrating the interlocking and ATP systems, and combining the transceiver and PA. In addition, total costs and space requirements have been dramatically reduced compared to conventional equipment by getting rid of solenoid relays to enable direct control of field devices.

(4) Better maintainability and faster recovery when problems occur

Continuous monitoring and collection of data regarding the operating state of equipment enables timely maintenance as well as rapid troubleshooting and recovery in the event when problems occur.

CONCLUSIONS

This paper described the evolution of interlocking equipment and ATP systems, culminating recently in the integration of the two systems in SAINT. Hitachi remains committed to technological innovation and provisioning new products and solutions to meet the ever-changing needs of railway operating companies and contribute to society at large.

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