Improvement of Track Work Units and Portable Units for the Shinkansen Maintenance Work Safety System

Atsushi Sasaki* Takeshi Kato** Jun Tabuchi**

The JR East Shinkansen maintenance work safety system has been contributing to the safety of maintenance work on Shinkansen lines. This system has functions developed in fiscal 2001 for preventing maintenance vehicle collision and protecting closed track sections, and functions developed in fiscal 2007 for preventing points from being forced open and preventing intrusion into unapproved sections. However, in simple work that accounts for the majority of maintenance work and work in sections where maintenance vehicles pass on the adjacent lines, work safety is still secured by the attention of lookouts and by portable units that emit an alarm at every signal received from the maintenance vehicle regardless of distance. Thus, for further safety improvement in the Shinkansen maintenance work, we have developed a new track work unit, onboard unit and portable unit that are compatible with simple maintenance work and maintenance vehicles passing on the adjacent line. Results of functional verification of those units on main lines were favorable, and we are now making preparations to put them into practical use.

**Keywords:** Shinkansen, Time-division multiplex communication, Protection of work section, User interface

1 Introduction

In Shinkansen maintenance work, there is no risk of collisions between Shinkansen trains and maintenance vehicles as the work is performed within maintenance work time that is completely separated from train operation time. Still, in the maintenance work time, there remains the risk of collisions between maintenance vehicles and risk of accidents involving workers. The Shinkansen maintenance work safety system (Fig. 1) was introduced in fiscal 2001 with the aim of preventing collisions between maintenance vehicles and intrusion of maintenance vehicles into closed track sections (now called “track work sections”). After that, we developed a device for preventing points from being forced open that prevents maintenance vehicles from forcing open points and intruding into unapproved sections that could cause serious operation disruptions, and we equipped all of Shinkansen maintenance vehicles with the device by fiscal 2007. This article will explain the development of new track work units for further safety in maintenance work on tracks and preparation for their deployment.

2 Overview of the Shinkansen Maintenance Work Safety System

The Shinkansen maintenance work safety system consists of onboard units that are installed on maintenance vehicles, track work units placed in track work sections and portable units carried by workers. When a maintenance vehicle approaches another maintenance vehicle or a track work section, the units activate an approach alarm, and the system stops the approaching maintenance vehicle if necessary.

2.1 Collision Prevention Function

When the Shinkansen maintenance work safety system was first introduced, the maintenance car would obtain its information on its own location by the speed sensor installed onboard. It would obtain location information of other maintenance vehicles and of wayside work by wireless communications. If there was a risk of a collision, the system would activate alarms. If the maintenance vehicle continued to approach, the system would automatically apply the brakes of that vehicle (Fig. 1).
2.2 Function for Preventing Points from Being Forced Open

The introduction of the aforementioned safety system achieved prevention of collisions between maintenance vehicles in sections between stations. However, checking route directions of points when running within the station yard and preventing intrusion of maintenance vehicles into unapproved sections still relied on human attention. Therefore, there were still risks that could lead to accidents such as forcing open or damaging points and derailment of maintenance vehicles. The risk of collisions between maintenance vehicles in the station yard also remained since the system did not have information on the numbers of the lines where maintenance vehicles are located.

To overcome those issues, we developed an onboard unit with the function for preventing points from being forced open. The device recognizes the location of maintenance vehicles in the station yard, numbers of the lines occupied by the maintenance vehicles and route directions of the points based on route information of the maintenance vehicles obtained by connecting the unit and handy terminals of the maintenance work control system, a sub-system of COSMOS (Computerized Safety Maintenance and Operation Systems of Shinkansen). That enabled automatic stopping of maintenance vehicles in the station yard if risk of points being forced open, intrusion into unapproved routes or collisions between maintenance vehicles is detected.

A touch screen monitor was added to the cab of maintenance vehicles, providing a function for real-time display of line diagrams, locations of vehicles and route information. With that, we aimed to improve functionality of the user interface.

Fig. 2 shows the system configuration of the onboard unit with the function for preventing points from being forced open, and Fig. 3 shows an example of the monitor screen of the device.

2.3 Issues with the Current Safety System

The aforementioned collision prevention and forcing open points prevention functions are functions of the onboard unit for maintenance vehicles. On the other hand, functions of track work units and portable units used in the track work sections remain as they were just after development (fiscal 2001). Thus, the functions have the following issues from the viewpoint of protecting workers from running maintenance vehicles.

(1) Track work units can be set for either inbound or outbound line only. If a maintenance vehicle passes on the line adjacent to the set work section, neither the maintenance vehicle nor track work units can recognize the location or approach of the other since different frequencies are used for inbound and outbound lines.

(2) Since the location of the maintenance work site is set as a point of kilometerage, work sections are not protected as a specific range (XX km XX m to XX km XX m).

(3) In maintenance work in a station yard, the number of the line cannot be set (only inbound/outbound line can be set).

(4) Portable units emit an alarm at every signal received from maintenance vehicles, so some unnecessary alarms are also emitted.

(5) Since simple maintenance (hereinafter “repair”) work is covered only by portable units, appropriate alarm activation is not performed according to maintenance vehicle locations.
To improve wayside worker safety, we decided to develop a new track work unit to solve the aforementioned problems. Issues that needed to be solved are as follows.

1. Development of a new communication control method
   - Two-frequency search for inbound and outbound lines (automatic switch-over)
   - Setting of a work section range (XX km XX m to XX km XX m)
   - Increased number of units that can communicate (to handle increase in types of work)
   - Setting of work type (classification of track work or repair work)
   - Display of work locations and maintenance vehicle locations on the monitor screen
2. Base station and terminal system for track work units and portable units
   - Grouping of a base station (track work unit) and terminals (portable units)
   - Activation/deactivation of terminals alarms at a command from the base station
3. Downsizing of track work units
   First of all, we decided to undertake development of a new communications control method that is the core technology to achieve those new functions.

### 3.1 Basic Tests of the New Communications Control Method
Since the current track work units use different radio frequencies for inbound and outbound lines, two units are needed when work is done on both inbound and outbound lines. However, both inbound and outbound lines should be handled by a single unit. In order to handle repair work, the number of types of work covered would increase too. Moreover, data for the set kilometerage would increase to allow input of the work site location as a specified range (XX km XX m to XX km XX m) from a single point of kilometerage (XX km XX m). The increased communications data thus needs to be processed by effectively using limited wireless communications data.

For those issues related to effective use of communications data resources, we conducted basic tests to check whether changing the communication format could handle increased communications data and test whether wireless communications control could be applied to practical use. Fig. 4 shows an overview of the basic tests.

The basic test results demonstrated that the following functions could be covered.

1. Inbound/outbound line distinction by two-frequency search
   - Alarm activation and display function at approach of a maintenance vehicle on the adjacent line
2. Wireless communications function for 30 cases of work simultaneously per unit
   - Compatibility with increase in applicable work
3. Grouping of a track work unit and portable units
   - Alarm activation on portable units according to the distance to the approaching maintenance vehicle
4. Setting of new types of work
   - Ability to set repair work as well as track work
   - Ability to make appropriate brake control for maintenance vehicles (brake control in track work, approach alarm only in repair work)
5. Input of work section as a range
   - Setting the work range as XX km XX m to XX km XX m
6. Setting of the number of the line in work in a station yard
   - Improvement from setting of inbound or outbound only to ability to indicate per line such as inbound No. 1, inbound main line etc.

### 3.2 Production and Test of Prototype New Track Work Unit
Based on the basic tests of the communications control method, we made a prototype of the new track work unit incorporating the aforementioned functions, and we carried out tests to verify correct operation of the prototype.

The test results of the prototype of the new track work unit are as follows.

#### 3.2.1 Input Function
Taking into account ease of input and of reading work section and maintenance vehicle locations, we adopted a five-inch touch panel type color display for the new track work unit. As shown in an example of specific input in Fig. 5,
following items are input by a list or with a numeric keypad. The order of input is as follows.

(1) Input work type
Choose from "track work only", "repair work only" or "track work and repair work".

(2) Input line
Choose the name of the line (Tohoku, Joetsu, Hokuriku, Gala) where work will be done.

(3) Set work section range
Input the kilometerage of the work section by setting the start point then the end point on the numeric keypad.

(4) Set work section line number
Up to two adjacent lines (inbound main line and outbound main line, inbound No. 1 line and inbound No. 2 line, etc.) can be set simultaneously with one unit.

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**3.2.3 Test Results of Data Transfer to and from Maintenance Vehicles**

By communicating between the new track work unit and the onboard unit of the maintenance vehicle, the location of the maintenance vehicle is displayed on the track work unit monitor, and the wayside work section, line number and work type are displayed on the onboard unit monitor. Necessary alarms are activated on both units at appropriate times, and brake control of maintenance vehicles activated. The items confirmed in the tests were as follows.

(1) Control by work type

i) Using wireless communications data received from the new track work unit, the onboard unit clearly displayed the work type in the wayside work sections (track work, repair work). The adjacent line protection sections based on the work sections were displayed too.

ii) When maintenance vehicles with the onboard unit approached each section (track work section, repair work section, adjacent line protection section), the approach alarm was properly activated. When they approach the track work section, necessary brake control was performed.

(2) Work section range control

i) The range of the work section (XX km XX m to XX km XX m) and the line number were clearly displayed.

ii) We confirmed that the onboard unit alarm activated while the maintenance vehicle was passing through the repair work section and the adjacent line protection sections. For the case where the maintenance vehicle was passing through the track and repair work section, the system was designed not to activate the alarm of the track work unit to avoid confusion with approach alarms of other maintenance vehicles.

(3) Control in a station yard
We confirmed that the line number of the work section was indicated. We also confirmed that the approach alarm of the onboard unit activated only for necessary lines.

(4) Emergency stop function
We confirmed that the ON/OFF status of the emergency stop button could be identified on the onboard unit by operating the emergency stop button equipped to the new line work unit and that the emergency stop function properly worked.

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**3.2.4 Downsizing**

To make the track work unit easier to transport, its dimensions and weight were reduced to around 1/3 those of the current unit. Fig. 7 shows the comparison.
4. Development of a New Portable Unit

The current portable unit was designed to activate an alarm when it received the signal from an onboard unit of a maintenance vehicle, regardless of the distance of the approaching maintenance vehicle or its location (on the main line or in the depot yard). Thus, we adopted a system where the alarm command by the new line work unit activates an alarm according to the distance of the approaching maintenance vehicle. In consideration of costs at introduction, we developed the alarm control program only, using the same mechanical structure as the current unit.

4.1 New Functions of the Portable Unit

New functions of the new portable unit are as follows.

(1) Base station/terminal grouping operation
   i) A track work unit (base station) and portable units (terminals) are set in a group.
   ii) Once grouped, the set groups are kept even when a wireless signal for grouping is received from other track work unit.

(2) Alarm activation at approach of maintenance vehicles
   i) At approach of maintenance vehicles, the portable unit receives control data from the specified wayside unit in the group, and an alarm is activated according to the distance of the approaching vehicle.
   ii) When not grouped with a track work unit, an approach alarm is activated when wireless signals are received from maintenance vehicles. This is the same as is currently used.

4.2 Improvement of Track Work Unit

We added the grouping function to track work units to give the aforementioned function to portable units.

The details of improvement are as follows.

- Grouping of portable units is performed on the main screen of the track work unit using a function button.

The results of grouping tests confirmed that the improved grouping function works properly.

5. Overall Field Tests

From January to February 2010, we carried out overall functional verification tests combining the developed track work units, portable units and onboard units on a main line that includes the junction of the Joetsu Shinkansen and Nagano Shinkansen.

By running a maintenance vehicle on that line, we checked communication distance, alarm activation and timing of braking, confirming that the required functions were met.

6. Conclusion

The functions of the new Shinkansen maintenance work safety system are as shown in Fig. 8. Wayside work is displayed at maintenance vehicles, and maintenance vehicles are displayed at the wayside. Approach alarms are activated on both units, and necessary brake control is performed for maintenance vehicles.

With portable units, an alarm is activated taking into account of distance from and running direction of the maintenance vehicles. This will enable further improvement in safety of Shinkansen maintenance work.

Since the end of fiscal 2010, we have been making final checks of the functions and preparing for instructional meetings with an aim of starting practical use of the new track work units equipped with some of the developed functions.