**Development of a Train Approach Alarm for Lines Without Track Circuits**

The TC type train approach alarm, which detects trains by track circuits, is widely used by JR East as a device to announce train approach. However, it had not been introduced to lines without track circuits, such as those with semi-automatic block systems. Therefore we developed a new train approach alarm that estimates train and worker positions by GPS, transmits train positions by mobile phone and licensed mobile radio, and emits an alarm to notify according to the approach distance of trains. We will work on introducing the alarm to applicable lines in future.

**Keywords:** Train approach alarm, GPS, Tachogenerator, Mobile phone, Licensed mobile radio

### 1 Introduction

Railway construction and other work on or close to commercial lines is usually carried out upon taking line closure procedures by activating a red signal to prevent train entry so as to avoid accidents such as workers being struck by a train. In simple work such as surveys, however, lines are not always closed. Workers often perform the job on operating lines, leaving the worksite when signaled by train lookouts positioned that a train is approaching. Worker safety thus depends on the attention of the train lookouts.

In order to improve worker safety, JR East thus developed the TC train approach alarm (hereinafter, “TC alarm”), a safety system that supports the work of lookouts by sounding an alarm and vibrating when a train approaches.

The TC alarm activates by detecting train line occupation information using track circuits. Track circuits detect electric short-circuiting between right and left rails through an axle of a train vehicle to identify line occupation status, so TC alarms could not be introduced to sections without track circuits.

In 2008, however, a mistake resulting in workers not leaving the track occurred on the Suigun Line, which does not have track circuits. In light of that incident, we undertook development of a train approach alarm that can also be introduced to sections without track circuits.

### 2 Overview of the Alarm System

#### 2.1 System Configuration

The alarm system consists of the components shown in Fig. 1. Table 1 lists major functions of individual components.

The data transmission method of the alarm system is as follows.

1. **Train detection**
   
   GPS receivers equipped to an onboard device and base station terminals for workers constantly identify the position of trains and workers. That location information is transmitted to a central unit via a mobile phone network.

   The onboard device obtains data from a tachogenerator. So, by using a function for calculating distance traveled, it can identify the position of the train even if GPS positioning temporarily cannot be used.

2. **Obtaining Train Information**
   
   The central unit consists of a train information obtaining unit that obtains the train number, delay time if any, and line occupation information from the Centralized Traffic Control (CTC)/Traffic Information Display (TID) and a central server.

   The central server converts the train location information from the onboard device to route kilometerage and compares that with the information from the train information obtaining unit to create train information that includes location.

3. **Providing the Base Unit of the Handy Terminals for Workers with the Information**
   
   The train information created by the central unit is transmitted...
Field Tests 3.1 Field Tests Using a Prototype

After the start of development and basic function tests, we carried out field tests of a prototype system consisting of components including onboard devices, a central unit, and terminals for workers. The field tests were performed from May 2011 on the Hachiko Line as a model line.

In the field tests, one testing personnel carried an onboard device on a DMU and other personnel stood at a level crossing with a terminal for workers as shown in Fig. 4, and we checked the alarm operation. This was done to verify GPS positioning and communications of the prototype system via mobile phone and licensed mobile radio networks.

The test results demonstrated that the system operated correctly for sound indicating normal operation, train approach caution, train approach warning, and stopping of the alarm after the train passes.

The test results also confirmed that the base station terminal correctly controlled the handy terminal for workers in alarm activation and alarm stopping.

2.2 Display Screen of Base Station Terminals for Workers

The base station terminals for workers display train numbers, locations, delay time if any, approach distance, and speeds of the inbound and outbound trains nearest to the worksite. An alarm is activated according to the distances to those approaching trains (Fig. 2).

2.3 Alarm of Base Station Terminals for Workers

Fig. 3 shows typical cases in which alarms are emitted.

A base station terminal constantly calculates track distances from the worksite to the approaching trains based on its own position obtained from railway GIS data through GPS positioning and train positions obtained via mobile phone and licensed mobile radio networks.

When no inbound or outbound train is located within 3,000 m of the worksite, the base unit beeps to inform that it is operating normally. When a train approaches at a distance less than 3,000 m from the worksite, the base unit issues a train approach notice with a caution announcement and vibration, and the background color of the screen of the base station terminal changes to yellow. And, when a train approaches even closer to a distance less than 1,500 m, the base unit issues a train approach alarm with a warning announcement and vibration, and the background color of the screen of the base station terminal changes to red. After the train passes the worksite and is detected to be 100 m away, the base station terminal stops emitting an alarm. In this way, the base station terminal informs workers of approach of trains with sound and display color.

3 Field Tests

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Fig. 4 Field Test of Prototype System
3.2 Installation of Onboard Devices to Rolling Stock
Since we were able to obtain favorable results in the field tests using an onboard device on an actual DMU, we installed that device to all DMU trainsets used on the Hachiko Line in March 2012. Fig. 5 shows an onboard device and an antenna installed to a DMU.

From June to August 2012, we conducted work to connect a cable from the tachogenerator to the onboard device in each DMU.

![Image](363x315.png)

**Fig. 5** Installation of Onboard Device and Antenna

3.3 General Function Tests on the Hachiko Line
As installation of onboard devices to all DMU trainsets for the Hachiko Line was completed, we carried out general function tests to verify GPS positioning, communications via mobile phone and licensed mobile radio networks, and alarm emission operation of the prototype system in a trial environment.

In the general function tests, we checked not only the alarm emission operation for ordinary approaching and passing trains, but also for approach of vehicles that only happens a few times a day. In those tests, we verified functioning in case of errors in components and the like.

Major items checked are as follows. The test results verified that the system operated properly as designed in all of the following cases.

1. Operation when an approaching train occupies the line in the yard of the nearest station due to a red departure signal
2. Operation when a train turns back at, ends operation at, or departs from an intermediate station
3. Operation when both inbound and outbound trains approach at the same time
4. Operation in mobile phone network failure
5. Operation in licensed mobile radio failure
6. Operation when base station terminals for workers continuously are unable to perform GPS positioning
7. Operation when the data from CTC/TID cannot be obtained

3.4 Alarm Emission by Vehicles Without Onboard Devices
In order to alert workers of an approaching vehicle (train) without an onboard device, we added to the system a function to start emitting an alarm when train information from CTC/TID indicates a vehicle (train) occupies the line at a location two sections ahead of the worksite and stop emitting an alarm when that vehicle (train) passes the worksite (Fig. 6).

To verify the function, we carried out operation tests on a day when a special train ran on the Hachiko Line. As a result, the system correctly emitted an alarm and displayed the train information on the screen of the base station terminal and otherwise operated as designed, even though the speed of and distance to that train were not displayed.

![Image](439x15.png)

**Fig. 6** Alarm Emission at Approach of Vehicle Without Onboard Device

3.5 Effect of Tree Growth Along Line on GPS Positioning
There was a concern that, in summer, trees taller than workers along the line could block GPS positioning of the terminals for worker when they leave the track due to approaching trains. We thus walked along the line in a section with particularly thick tree growth to check the effect of the trees on GPS positioning (Fig. 7). As a result, the rate at which GPS positioning of the base station terminal could not be done was 2.1% (359/16,980 units of data).

![Image](549x14.png)

**Fig. 7** GPS Positioning Check

GPS positioning temporarily could not be done near tall trees and overbridges; however, it was restored soon and continued working after recovery. We thus determined that there was no restriction on use even in such a section.

Based on those test results, we conducted test operation of the prototype system with some field offices for equipment maintenance from November 2012 to March 2015.

### 4 Downsize of Base Station Terminal
A field office participating the test operation commented that the dimensions (177 × 142 × 52 mm) and weight (1.3 kg) of the base station terminal made it too large to carry while patrolling along the line. For that reason, we undertook efforts to reduce the size of the terminal.

After considering various factors, we decided to use a general-purpose terminal for the control and display functions of the base station terminal, and we developed a new compact radio terminal for the licensed mobile radio that can connect to the general-purpose terminal via Bluetooth (Fig. 8).
For the general-purpose terminal (hereinafter, “smartphone-type worker terminal”), we selected a model with compact size and light weight (140 × 72 × 12 mm, 140 g) from commercially available tablet and smartphone products. It was selected from viewpoints such as operating time (battery duration), GPS positioning performance, and screen visibility (less reflection of sunlight).

We also improved some functions based on comments from users in the test operation in when replacing the base station terminal with the smartphone-type worker terminal. Those include reduction of noisy tones by changing the interval of the normal operation beep from two seconds to four seconds and changing the warning announcement and vibration, from continuous to three-second intervals.

Previous base station terminal

| Weight: 1,300 g | Dimensions: 177 × 142 × 52 mm |

Smartphone-type base station terminal

| Radio function | Control, display, and GPS functions |

Compact radio

| Weight: 300 g | Dimensions: 56 × 29 × 104 mm |

| Weight: 140 g | Dimensions: 140 × 72 × 12 mm |

Fig. 8 Downsizing of Base Station Terminal

5 Adaptability to Tunnels

5.1 Signal Check in Section with Tunnel

It was expected that the system could not be used in sections where tunnels or other structures cover the track and block GPS positioning and communications via mobile phone network.

Many of the lines where the system will be introduced have tunnels, and thus making the system usable even in tunnels the same as in open sections was an issue to overcome. In light of that, we started development functions to adapt to use in tunnels with the Iiyama Line as the model line.

In winter (February) and summer (September) 2012, test personnel carried an onboard device on a train on the Iiyama Line, and at the wayside they carried the base station terminal and the terminal for workers. Those were used to check GPS positioning, connection via mobile phone and licensed mobile radio networks, and the emission of alarms.

As a result of the tests, GPS positioning and communications via the mobile phone network were blocked in the tunnel but immediately restored after the train passed the tunnel. We also confirmed that 2 m or higher snowpack in winter or thick tree growth in summer along the line did not block GPS positioning and communications via mobile phone and licensed mobile radio networks.

5.2 Consideration of Functions for Adapting to Tunnel Sections

To deploy the system to other lines, we need to allow GPS positioning and communications via a mobile phone network even in tunnels. We are thus examining functions for adapting on the Iiyama Line, which has tunnels.

We checked the signal status on the Iiyama Line with an onboard device on one end of the vehicle (the specification tested on the Hachiko Line) when the vehicle entered a tunnel. As a result, the base station terminal could connect well with the licensed mobile radio when the base station terminal was on the same end of the train as the onboard device. However, the car body blocked the signal and the connection deteriorated when the base station terminal was on the end opposite that of the onboard device. Based on these findings, we installed an onboard device to both ends of the vehicle on the Iiyama Line.

For use in long tunnels where licensed mobile radio signals do not reach, we will set up a wireless LAN in the tunnel to transmit train location and other information via wired connection to a position where the signal can be received. We are now preparing for field verification tests of this function (Fig. 9).

Fig. 9 Application to Tunnel Sections by Wireless LAN

6 Future Plans

We will review the results of fields test of the prototype system with the functions for application to tunnel sections on the Iiyama Line and test operation by the staff of field offices. Based on those results, we will determine on the final specifications of a safer train approach alarm system with the head office Facilities Department and aim to deploy the system to other lines.