Advanced automatic train protection system
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Abstract

We are developing Advanced Automatic Train Protection system to resolve some problems in the existing ATP. In the existing ATP, only a speed signal which specifies the maximum speed on each block section is transmitted to an on-board processor through the track circuits by using combination of two signal frequencies. On the other hand, in the advanced ATP, complicated message such as the distance to the preceding train and position of the actual train are transmitted through the rails by using digital codes. An on-board processor generates a braking pattern corresponding to its own braking performance and the speed restriction on switches and applies the brake automatically if the actual train speed exceeds the calculated value. Using track circuits for transmitting is reliable theoretically, but the traction current may interrupt a normal transmission of data and a large leakage conductance may force the track circuit length to be shortened. So the carrier frequency should have the same band as the present ATP(700-1200Hz). A minimum shift keying (MSK) system is preferable for this system.

1 Introduction

Operating principle of the existing ATP is shown in Figure 1. The present system of ATP was introduced when the Tokaido Shinkansen opened in 1964. In the existing ATP, a speed signal which specifies the maximum speed on each
block section is transmitted to an on-board processor through the track circuits by using combination of two signal frequencies. If the driver ignores a command to reduce the speed, full braking is applied automatically. However, the brakes are released when the speed drops below the limit imposed by the ATP, and the driver can then take change again.

![Operating principle of ATP](image)

Figure 1: Operating principle of ATP

This results in a series of sharp decelerations as the brakes are applied and released, which detracts from ride comfort. It is clear that repeated application and release of the brakes, compared with the smooth braking curve, results in much longer headway. And when trains with different braking performances are operating on the same track, the block section length is determined by the train with the worst braking performance. This result in trains with superior braking performance slowing down earlier than is really necessary, and reducing the line capacity.
2 What is the Advanced Automatic Train Protection System?

The Advanced Automatic Train Protection System that we call Digital ATP, instead of modulating the track circuit carrier current at various frequencies, sends a digital message to an intelligent microprocessor on the train, thereby greatly increasing the amount of data that can be transmitted through the rails. Essentially, this message informs the following train on the distance to the preceding train or to the point of speed reduction such as the platform, turnouts, etc. So the driver can get an advance notice of the need to brake. Since ATP brake acts in one stage from full speed to stop, passengers feel comfortable. And another advantage of Digital ATP is that the on-board processor can be programmed to suit trains with different braking performances and maximum speeds.
With digital ATP, a train is detected in the normal way through track circuits. The rear limit of a block section occupied by a train is represented in the message as 0 unblocked section. The next block section in the rear is 1, followed by 2, 3 and so on. Each track circuit has its own ID, so that the track circuit actually occupied by a train may be identified in the digital ATP message transmitted to the following train.

A great deal of information about the route is stored in the microprocessor on board. This includes the location (measured from the terminus) of each track circuit; sequence of track circuit numbers; the location and severity of curves and gradients; and location of turnouts together with the maximum speed at which they can be traversed.

The distance between the two trains can be calculated using the track circuit number received by the on-board equipment, and the number of unblocked sections. The braking curve from the present location of a train to the preceding train is calculated by combining this with stored track data.

The braking curve is used to calculate the limit speed at any instant, and this is compared with the actual speed. When the two speeds converge, an alarm sounds to alert the driver. When the train speed surpasses the limit speed, the brakes are applied. Present speed, limit speed, distance between a train and the preceding train, and the braking curve are all displayed in the cab.

As a train moves ahead, its location within the track circuit is determined by an axle rotation detector. Absolute location is deduced from the fact that, when the train advances into a track circuit, the carrier for train detection changes.
Ground equipment

The ground equipment is shown in Figure 3. It uses non-insulated track circuit, so it works with existing train detecting device.

As track circuits are used to transmit the digital message, they must be immune to electromagnetic interference from traction current. Almost all the interference frequencies of traction current are odd harmonics, and should be avoided. In the case of 60 Hz, the principal harmonics emerge at intervals of 120 Hz - that is, 180, 300, 420 and so on.

The power synchronous minimum shift keying (MSK) system is preferable for digital ATP (Figure 4). This is a modulation system in which digital signals are transmitted at high speed within a narrow band to avoid the interference frequency for synchronizing the signal carrier frequency (Figure 5). MSK achieves a transmission speed which is numerically almost the same as the bandwidth of a receiving filter. In this test field, frequency of power is 60 Hz, so avoiding a harmonic frequency of 120 Hz means that a bandwidth of about 100 Hz is available for the receiving filter. In this case, the maximum
transmission speed is about 90 baud.

![Diagram](image)

**Figure 4: Power synchronous Minimum Shift Keying**

Data transmitted includes the track circuit ID, the number of unblocked sections, and the route set for the train; 34 bits are allotted for these items. To ensure that the code is not corrupted, a cyclic redundancy check is needed which requires 8 bits. This means that 42 bits are required in all, but the total is raised to 48 bits when codes for frame transmission are added. These codes are repeatedly transmitted through the track circuit.

Transmission can take place at 1.9 times/sec. It takes 0.5 sec to receive the data. At the boundary of a track circuit, an extra 0.5 sec is required for the timing of the frame transmission.

![Data Format](image)

**Figure 5: Data Format**
On-board equipment

Microcomputers will be used on the train to process the signals received from the wayside via the track circuits. The approach to safety is the same as for wayside equipment, and for reliability, the on-board equipment will also be duplex.

Figure 6 is a block diagram of the equipment on the train. ATP signals and track data are picked up by two coils. Using a brake pattern generator, a braking curve is calculated from location and output of axle counter. Through the speed check and brake control device, the present train speed and the speed limit are compared to control the brake. These speeds are displayed in the cab for the driver, who should normally control his train so that ATP braking is not necessary.

![Block diagram](image-url)
Figure 7 is the cockpit view of test train. The driver can apply the brake looking cab display (Figure 8). Concurrently, we will design the man-machine interface more useful for drivers. We try designing another interface fitting existing ATP system.

Figure 7: Cockpit view

Figure 8: Graphics of cab display
3 Result of field tests

We tested this system in Kagoshima Line belonging to JR Kyushu. We set a virtual turnout and platform in test line of 6 blocks like Figure 9. Contents of the test is described below.

1. Verification of calculating the actual train position
2. Braking performance test
3. Drivability test

![Diagram of field test context](image)

**Figure 9: Context of field test**
Figure 10 shows the result of basic running test in this test field. We confirm the stability of this system.

4 Conclusions

We are developing a digital ATP as an ATP for Shinkansen which will replace the conventional ATP. The almost completed system design have finished. The performance of the digital ATP system will be confirmed on the test line prior to its implementation. Furthermore, after a minor modification, the narrow-gauge line version of digital ATP system is due to be developed for inter-city lines and commuter lines.

References