Radio Data Transmission Tests in ATACS
(Advanced Train and Administration Communication System)

1. Introduction

Railway control systems have so far been introduced to prevent two trains or more from existing in one of the same block sections by displaying the position of the train detected by the track circuit on the signal.

This has ensured the safety and transport efficiency to a constant level, but such system is controlled collectively by the wayside facilities, and this poses a problem of the high modification cost to improve the train speed and shorten the headway, and cutting down on equipment investment cost and maintenance cost.

However, remarkable progress made in the field of information technology including mobile communication technology has enabled to collect and send a variegated information. Such technologies can also be introduced in the railway control systems to solve the aforesaid problem.

Therefore, with a view to a full model change of the railway control system, a safe, simple and highly reliable railway control system ATACS (Advanced Train Administration Communications System) has been developed as a substitute to the conventional control system based mainly on wayside facilities. In the new system the wayside and on-board control operations are re-arranged functionally using the information technology and general-purpose computer technology.

The train control system by radio is being developed also in any other countries than Japan. In Europe, ERTMS (European Rail Traffic Management System)/ETCS (European Train Control System) is being developed. ATACS is equivalent to the level-3 of the ERTMS/ETCS. In addition to these systems, there are many others such as the FFB for local lines being developed by German Railways, the RBS by Swedish National Railways and the AATC being developed in the USA.

East Japan Railway Company developed system specification, conducted the control run test with actual train and verified the performance of a system. Mitsubishi Electric Corp. did specification examination in the manufacture stage, manufactured radio equipment, performed data collection by the control run test with actual train and checked the performance of the equipment.

We had carried out the control run test with actual train in the Senseki Line of East Japan Railway (Fig. 1) for two years starting from 1997 to learn the propagation characteristics of the digital radio and to confirm the basic train control functions based on the radio data.

Presently we have developed a radio unit based on the narrow-band digital radio standard and have conducted the control run test for six months since October 2001.

In the control run test with actual train the following three items were verified in an attempt to prove the feasibility of the train control system using a digital radio system.

- Detection of train location
- Transmission of control data by digital radio
- Train interval control

This paper describes the results of the control data transmission test by using digital radio system.

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2. **Test System Configuration**

Fig. 2 shows the configuration of the ATACS test system. The system is composed of the command unit, ground controller, radio base station, on-board mobile radio station, on-board control unit and radio monitoring system. The ground units are all connected to the private network (an exclusive line) of the Railways Company.

Command unit is connected to each ground controller to deploy the control functions such as traffic control and system control.

Ground controller has the functions such as train location, interval control, yard route control, level crossing control and maintenance work administration and control.

Radio base station connected to the ground controller performs the function of transmit/receive information to/from the on-board mobile radio station by the digital radio.

On-board mobile radio station, which is used for radio transmission with radio base station, transmits the control data from ground controller to on-board control unit, and transmits data on the train location data to ground controller by digital radio.

On-board control unit controls the train traffic according to the control data sent by the digital radio from ground controller, and transmits the train location data to the ground controller by the digital radio.

Radio monitoring unit connected to all radio base stations (2 stations) has the function of collecting logs concerning the status monitoring of the radio base station, control of the radio unit, failure of the unit and transmission quality.

The radio system in ATACS is composed of the radio base stations, on-board mobile radio stations and radio monitoring unit (the section indicated by a vertical arrow mark <↑> in Fig. 2). The outline of the radio system in ATACS is described below.
3. Outline of Radio System

A quick shift from analog communication to digital communication is seen in recent years. There are various reasons for this rapid shift. The main reasons, however, are efficient use of frequencies by narrow band/multiplex system, secrecy of communication and miniaturization of units.

In accordance with such trends, the railway radio system is also being shifted to digitalization.

The 400 MHz band frequencies are currently being used for the railway radio system. However, in Japan, the narrow-band digital communication is being standardized for the land mobile stations using the concerned frequency band for public utilities. (ARIB STD-T61)

3-1 Radio specifications

Under the movement in digital ratio as described above a new radio unit based on the standard specifications has been newly developed for the ATACS radio system. Table 1 shows the radio specifications.

<table>
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<th>Table 1 Digital Radio Specifications</th>
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<td><strong>Item</strong></td>
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<td>Frequency band</td>
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<tr>
<td>Band width</td>
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<tr>
<td>Transmit-receive frequency interval</td>
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<td>Access method</td>
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<td>Modulation</td>
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<td>Diversity method</td>
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<td>Train under control</td>
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<td>Aerial antenna</td>
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3-2 Functions

The functions of the radio system are described below in detail.

(1) Overall

- In order to ensure security, the encrypted LSI is mounted to realize encryption (coding) of the radio data between radio base station and on-board mobile radio station.
- An announcement type frame has been set to be able to notify the data to all trains in addition to the frame for individual train control.

(2) Radio base station

- The data from the ground controller is transmitted to the on-board mobile radio station and the data received from the on-board mobile radio station is transmitted to the ground controller.
- The transmission is equipped with a standby unit in duplex system so that one unit, if failed, can be switched automatically to the other unit. Two units of receiver are installed for diversity reception.
- Connected to the radio monitoring unit, the radio base station enables control and monitoring from the radio monitoring unit.

Fig. 3 and Fig. 4 show the appearances of the radio base station and of the machine room are shown respectively.

(3) On-board mobile radio station

- This station transmits the data from the radio base station to the on-board control unit, and the data from the on-board control unit to the radio base station.
- The transmitter is equipped with a standby unit in duplex system so that one unit, if failed, can be switched automatically to the other unit. Two units of receiver are installed for diversity reception.
- A hand-over function is realized by the on-board mobile radio station.

Fig. 5 shows the appearance of the on-board mobile radio station.

(4) Radio monitoring unit

- Connected to the radio base station, this unit controls and monitors each base station and collects logs.
3-3 **Strategy for improving transmission quality**

In the radio communication, a phenomenon called “Multi-path” occurs, where the direct wave travelling from transmitting point to receiving point along a straight line is interfered by the reflective wave coming in after being reflected by structure, etc.

In the mobile communication where transmitter and receiver are moving, the wave propagation path varies as time passes. Since the lengths of these paths vary individually, the combine phase also varies accordingly. This causes the amplitude/phase of the signal input to the receiver to vary, finally leading to a phenomenon called “Fading.”

In the mobile communication, the radio network quality apparently gets deteriorated due to the fading effect.

In ATACS, however, the following two methods are adopted so as to improve the radio transmission quality and to ensure an radio coverage of 99.9% along the line.

(1) **Diversity reception**

Using the space diversity system equipped with two receiving antennas, the maximal ratio combining is carried out after combining the two received waves to obtain maximum value of CNR.

(2) **Forward error correction**

When the data is transmitted, a check bit is added to the transmission data for correcting errors at the transmitting side (coding). The errors are corrected by means of the check bit at the receiving side (decoding).
4. Control run test with actual train

The control run test with actual train were conducted on the following four items by configuring an ATACS system along the Senseki Line.

- Radio test .... Transmission characteristics test by digital radio only
- Daytime monitor run test .... Long-term stability test of data transmission quality and ATACS system
- Nighttime control run test .... Comprehensive test of ATACS system including interval control test by actual brake control

4-1 Radio data transmission tests

In order to measure the BER (Bit Error Rate) of the radio unit, an actual train configured only by the radio system was used to conduct the field test (in the Senseki Line).

(1) Diversity reception
As described above, diversity reception is effective to prevent fading. In ATACS the waves received by two receivers are combined before carrying out maximum ratio synthesis to obtain maximum value of CNR. From the measurement result of the radio data transmission tests, it has been confirmed that the bit error rate gets improved by one digit from $10^{-4}$ to $10^{-5}$ by diversity reception.

(2) Forward error correction
In this ATACS, Reed-Solomon Code was used as an error correction, with the error correcting capacity being 8 bytes or less of random errors. In ATACS, errors in 360 bits (control data) are corrected by using 128 correction bits (check bits).

(3) From the result of the radio data transmission tests, it has been confirmed that the burst error (continuous error) hardly exists, and that when an error occurs, it is a random error of 1 or 2 bits.
4-2 Control run test

The control run test (train interval control) was conducted after finishing the commercial railway service. Fig. 2 shows the system configuration.

The transmission quality of a radio system cannot be made equivalent to that of a wired communication system. However, the quality can be improved by using the diversity reception and error correcting methods mentioned above. The railway control system was therefore designed by considering such radio network quality. In ATACS, messages were transmitted at the cycle of 1 sec. Failure in receiving the messages for a specified time period (3 sec. in the test) was interpreted as Uncontrollable, and the corresponding train was brought to a stop. By achieving the reception probability 99.9% for a piece of message in a radio zone, it is possible to obtain $10^{-9}$ as the probability of “Uncontrollable” when no messages can be received for 3 consecutive times.

The radio unit used in the test could not provide the target frame receiving rate of 99% at the initial stage. However, as the adjustment was advanced and various problems were solved, the target 99.9% of receiving rate was achieved.

Further, no failure in receiving the mass ages for 3 consecutive times occurred during the test, neither did any trouble caused by the radio system.
5. Conclusion

The main purpose of the radio system used in these control tests in the field was to establish a control data (information) transmission system by digital radio, and the initial target has been achieved with excellent results.
Fig. 1 Location of the Senseki Line in East Japan Railway

Fig. 2 Configuration of ATACS Test System
Fig. 3 Appearance of Radio Base Station
Fig. 4  Appearance of Machine Room in Radio Base Station

Fig. 5  Appearance of On-board Mobile Radio Station