Digital Train Radio System for Okinawa Urban Monorail and Tokyo Tama Intercity Monorail

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1. Introduction

High-quality, high-stability, and high-speed radio communication is essential between trains traveling at high speed and ground crews in order to satisfy strict safety requirements.

Mitsubishi Electric Corporation has been involved in many projects to switch train radio systems to digital radio, thus accumulating related technologies and know-how.

At present, an analog or inductive radio method is used for most train radio systems on private railways, subways, monorail systems, and new transportation systems. However, such systems will increasingly be switched to digital to improve the quality and reliability of radio channels and to add new values such as data communications and application linkage.

Accordingly, Mitsubishi Electric has developed a 150-MHz band digital train radio system featuring the latest technologies.

This paper describes the outline and advantages of the digital train radio system (Fig. 1) delivered to Okinawa Urban Monorail Inc. in 2016. In 2018, we also delivered a similar system to Tokyo Tama Intercity Monorail which features operating information distribution services as a new function. This paper also describes this new function.

2. Outline of the Digital Train Radio System

2.1 System configuration

The digital train radio system consists of a central control unit, base station systems, on-board systems, and other equipment. Digital radio channels are used for communication between ground crews and trains. Table 1 outlines the functions of the various units.

2.2 Radio specifications

The radio communication system between ground crews and trains uses digital radio channels by the frequency-division multiple access (FDMA) / single channel per carrier (SCPC) method. Table 2 lists the radio specifications.

2.3 Functions

The system has the following functions.

(1) Voice communication and broadcasting function

(i) Dispatching call: Communications between dispatchers and crews on all trains

(ii) Individual call: Communications between dispatchers and crews on a designated train

(iii) Emergency call from passenger carriages: Communications between dispatchers and

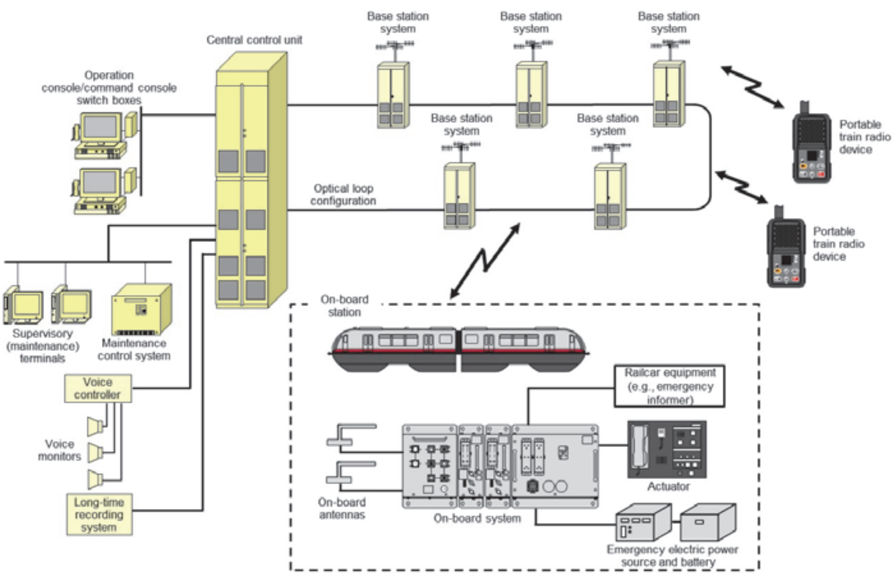

Fig. 1 Train radio system for Okinawa Urban Monorail lines

*Communication Networks Center

Table 1 Outline of functions of units

Unit	Location	Main functions
Central control unit	Central equipment room	(1) Controls voice communication and data communication channels (2) Interfaces with the base station systems (3) Interfaces with the operation console and external equipment
Base station system	Wayside	(1) Communicates with the on-board systems by radio (2) Interfaces with the central control unit
On-board system	Railcar	(1) Communicates with the base station systems by radio (2) Controls voice communications with dispatchers (3) Interfaces with other devices on trains
Operation console	Control center	(1) Works as a user interface with voice communications and data communications for dispatchers
Maintenance control system	Central equipment room	(1) Centrally manages information on supervisory control and maintenance
Portable train radio device	—	(1) Allows voice communications with dispatchers (2) Allows voice communications between maintenance engineers

Table 2 Radio specifications

Item	Specifications
Transmission line	Space wave/LCX
Access method	FDMA/SCPC method
Frequency band	150 MHz band
Frequency interval	6.25 kHz
Modulation method	π/4 shift QPSK
Transmission speed	9.6 kbps
Transmission power	Base station system: 4 W, on-board system: 1 W
Diversity configuration	Base station system: Transmission time diversity Receiver diversity On-board system: Receiver diversity

passengers on trains

(iv) Public announcements to an individual train: Broadcasting from dispatchers to passengers in a designated train

(2) Data transmission function

(i) Railcar dead-man notice: If a train crew member falls unconscious or a similar accident occurs while the train is traveling, the on-board system detects dead-man information and notifies the dispatchers of the abnormal state of the train crew member.

(ii) Emergency warning: In case of emergency (accident resulting in injury or death), a warning is issued to the control center and all trains. The power to the train may be cut to stop the train forcibly, depending on the details of the warning.

(3) Voice monitor function

(i) Voice monitor: Outputs the conversation between dispatchers and train crews to monitors in the central and station service offices.

(4) Call log function

(i) Call log: Records the conversation between dispatchers and train crews at all times.

(5) Remote supervisory control function

(i) Remote supervisory: Supervises and controls the operation statuses of various units and network channels remotely using supervisory (maintenance) terminals.

3. Advantages of the Digital Train Radio

3.1 Quality improvement by transmission time diversity and adaptive equalization

Generally, when the same signals in the same frequency are sent from multiple antennas, the radio waves disappear in the antiphase due to interference of the same waves, causing the signals reaching the receiving side to have large errors (Fig. 2). Such disappearance of radio waves periodically occurs depending on the frequency difference of the transmitters (beat interference).

To solve this problem, our system has transmission time diversity (1): it sends signals that were sent from adjacent base stations or antennas with a fixed time difference in order to avoid canceling each other out at the mobile station (Fig. 3). In addition, for mobile stations, an estimation technology by adaptive equalization (Fig. 4) is used, which makes it possible to use the aforementioned waves delayed by the transmission time diversity as signal components and to demodulate them. Furthermore, to improve the quality of radio channels, base and mobile stations feature receiver diversity.

3.2 Measures for blind zones and weak electric fields

New buildings and other factors may affect the radio wave environments in the vicinity and degrade the quality of the radio channels in the future. The degradation of channel quality in such cases can easily be eliminated simply by adding a base station or installing a satellite antenna to apply the anti-interference technology described in section 3.1 (Fig. 5).

3.3 Connection to railcar equipment

To cope with one-man operation, in this system, a railcar dead-man's device, emergency informers in passenger carriages, and public announcing device are connected to the on-board system. This enables the following operations in case a train crew member falls unconscious or another emergency occurs while a train is traveling as shown in Fig. 6: (1) The on-board system detects a dead-man notice, (2) a dead-man notice is sent to the dispatchers, (3) the dispatchers make a public

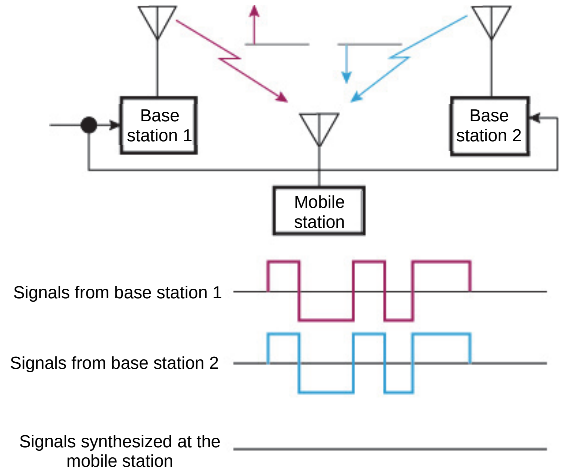

Fig. 2 Signal disappearance due to interference of same waves

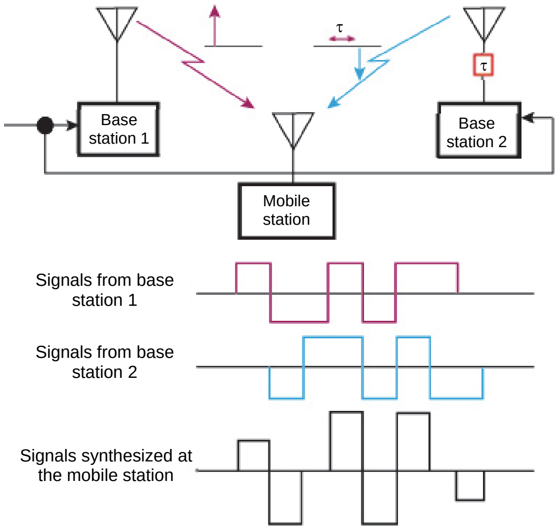

Fig. 3 Transmission time diversity

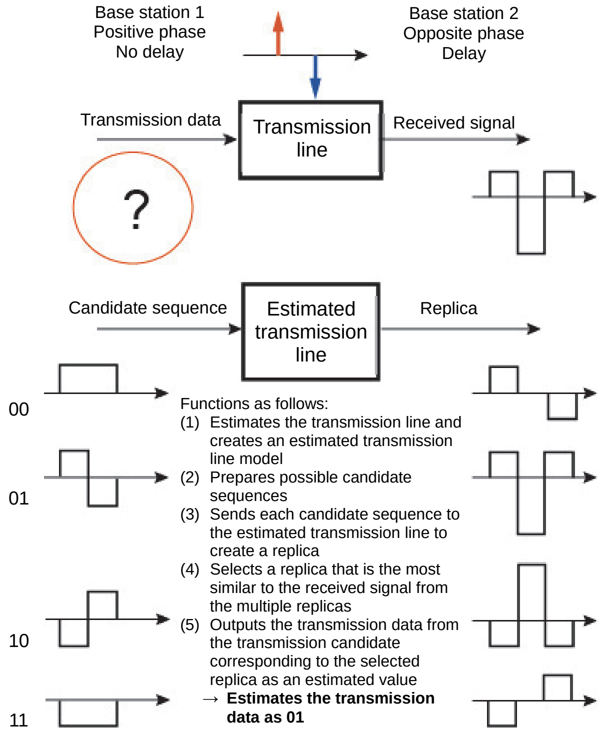

Fig. 4 Estimation by adaptive equalization

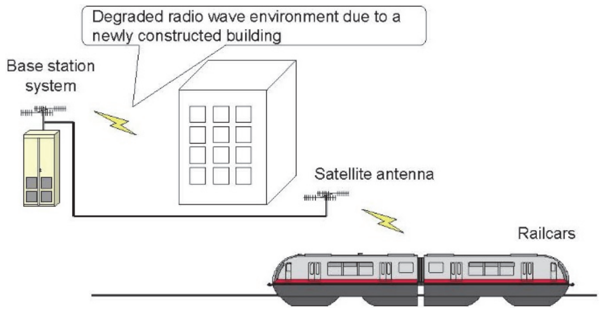

Fig. 5 Measures for blind zones and weak electric field

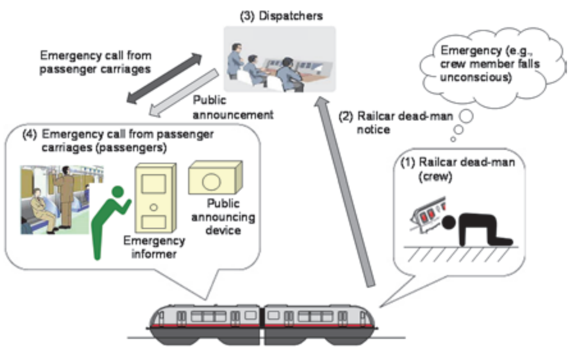

Fig. 6 Example connection with railcar equipment

announcement to notify the passengers of the situation, and (4) the emergency call function provided in the passenger carriages is used for communication between the dispatchers and passengers on the train. This system allows dispatchers to communicate with train crews and passengers on trains without fail in case of emergency.

3.4 Simultaneous transmission of voice and data

To ensure stable operation of trains, even during voice communications, a railcar dead-man notice and other important data need to be sent immediately. The radio sets of the system's on-board system and base station systems have a function for using a telephone communication channel and another function for using a control/data channel, allowing the two channels to be used at the same time. This ensures simultaneous transmission of voice and data. Figure 7 illustrates the on-board system configuration.

(1) Telephone communication channel

The channel is used for voice communications and broadcasting. Two channels are provided: a primary telephone communication channel and a secondary telephone communication channel.

(2) Control/data channel

The channel consists of a control channel used for communication control and a data channel for railcar dead-man notices and emergency warnings.

3.5 Clear sound quality by high sound quality voice codec

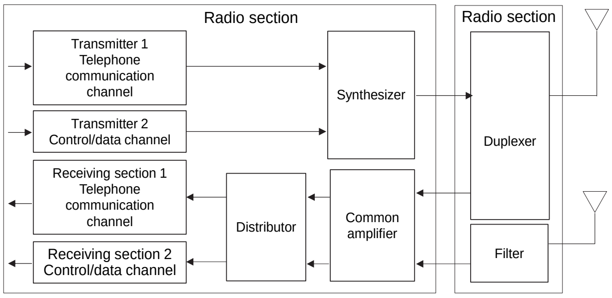

Fig. 7 On-board system configuration

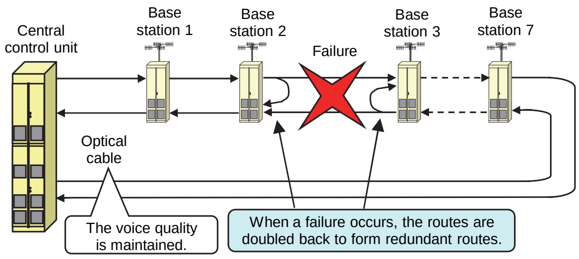

Fig. 8 Optical networking of approach lines

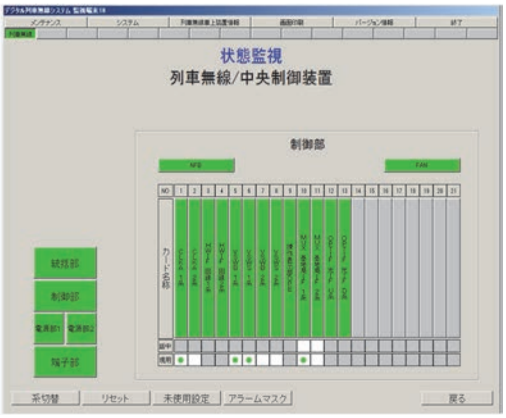

Fig. 9 Example screen of operation on supervisory (maintenance) terminal

This system uses our proprietary voice codec specific for train radio—Rail System-Code Excited Linear Prediction (RL-CELP). In the code configuration, priority is given to voice to ensure noiseless high-quality telephone communications in order to support accurate telephone communications between dispatchers on the ground and crews/passengers on the train.

3.6 Approach lines between the central control unit and base station systems

Optical networks using digital signals are used as approach lines between the central control unit and base station systems. The central control unit and all base station systems in the zone are connected in series using fiber optic cables. In such double-loop configuration, even if a failure occurs on a cable or at another section, the redundant configuration makes it possible to continue operation, enhancing the reliability (Fig. 8).

3.7 Higher maintainability thanks to remote supervisory control

Table 3 Radio specifications of portable devices

Item	Specification
Transmission line	Space wave
Access method	FDMA/SCPC method
Frequency band	150 MHz band
Frequency interval	6.25 kHz
Modulation method	$\pi/4$ shift QPSK
Transmission speed	9.6 kbps
Transmission power	0.8 W
Diversity	None

Supervisory (maintenance) terminals installed at operation bases have various functions: for remote supervision of the operation statuses of various devices and network channels; remote control of switching of the redundant sections in various devices; remote log collection for various devices; and downloading of software and other data. Figure 9 shows an example screen of operation on a supervisory (maintenance) terminal. These functions make it possible to supervise and control the statuses of various devices remotely from operation bases and eliminate the need for maintenance engineers to go to the devices installed at each station, which facilitates maintenance.

4. Functions Added to the Digital Train Radio

In addition to the advantages described in Chapter 3, the train radio system for Okinawa Urban Monorail lines includes portable train radio devices that can control telephone communication channels without involving dispatchers, thus reducing maintenance work. In addition, for the train radio system for Tokyo Tama Intercity Monorail lines, operating information distribution services that are combined with our full-color LED in-vehicle guidance displays are provided, improving the guidance services for passengers. The functions of these devices and services are described below.

4.1 Portable train radio devices that can select and control telephone communication channels

A conventional portable train radio device uses a fixed single telephone communication channel for communications. However, if multiple portable devices are used in a zone, it is difficult to share the single telephone communication channel. For the portable train radio devices for Okinawa Urban Monorail lines, a portable device can use two telephone communication channels, which is convenient for maintenance engineers. Figure 10 illustrates an example of channel control of portable devices, showing the flow from selecting a telephone communication channel to ending the communications (Table 3).

4.2 Higher added value thanks to operating information distribution services

Operating information distribution services are a

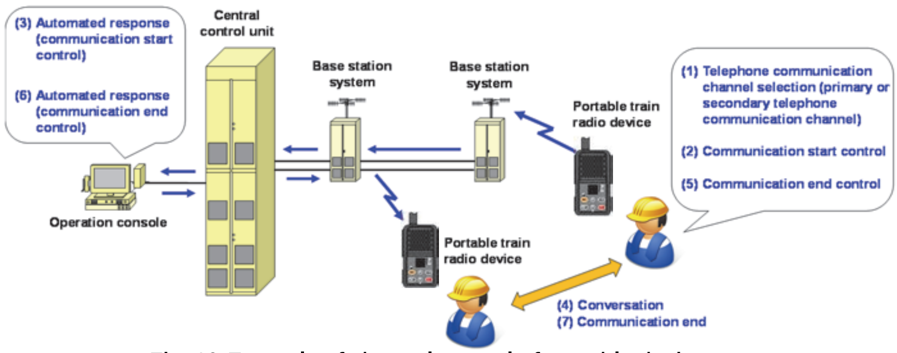

Fig. 10 Example of channel control of portable devices

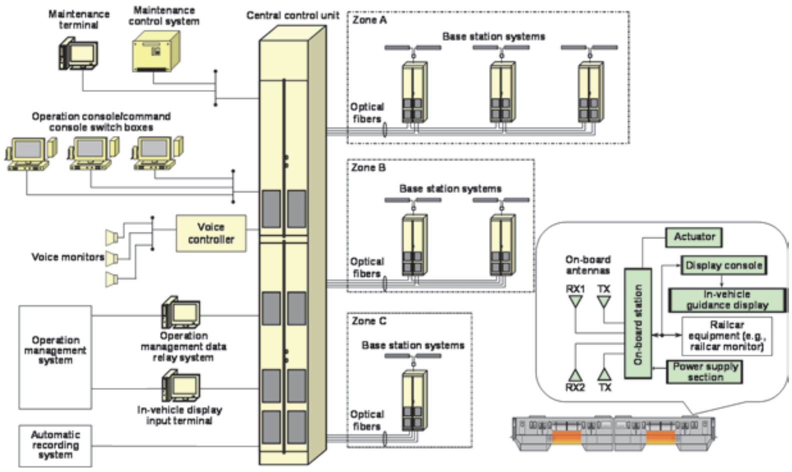

Fig. 11 Train radio system for the Tokyo Tama Intercity Monorail lines

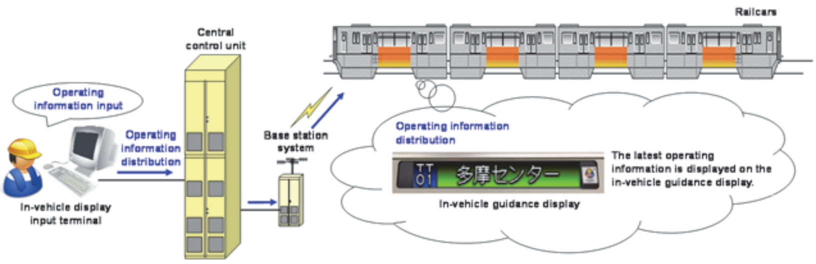

Fig. 12 Operating information distribution services

data transmission function introduced into the Tokyo Tama Intercity Monorail lines. The function sends the latest operating information (service statuses of various lines) to trains via the digital train radio and displays such information on the in-vehicle guidance displays in the passenger carriages. This function, made possible by cooperation between the train radio system and railcar system businesses of Mitsubishi Electric, improves the passenger services and adds value. Figure 11 shows the configuration of the train radio system for the Tokyo Tama Intercity Monorail lines. Figure 12 illustrates the operating information distribution service function.

5. Conclusion

This paper described the outline and advantages of the digital train radio systems delivered to Okinawa Urban Monorail and Tokyo Tama Intercity Monorail.

The digital train radio systems are mainly used for telephone communications at present. We will consider expanding the scope of application of the data transmission function to add new values, such as support for crews, better passenger services, crime prevention, and reduction of maintenance work, thus contributing to the development of the railway industry and establishment of social infrastructure.

We sincerely thank Okinawa Urban Monorail Inc., Tokyo Tama Intercity Monorail Co., and others for their support in developing these systems.

Reference

(1) H. Kubo, et al., Beat Interference Suppression Techniques by means of Transmission Diversity and Adaptive Equalization, Transactions of the Institute of Electronics, Information and Communication Engineers. B, J86–B, No. 3, 468–476 (2003)