Electronic Parking System for Singapore

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An Electronic Road Pricing (ERP) system was introduced in 1998 in Singapore to reduce the traffic congestion in the city area, almost all vehicles in Singapore are equipped with onboard equipment called in-vehicle unit (IU). Using these in-vehicle units and the technologies based on the ERP system, Mitsubishi Heavy Industries, Ltd. (MHI) has developed an Electronic Parking System (EPS) that enables settlement of parking fees without parking tickets and cash. In order to keep the compatibilities of current car park system, antennas were made smaller and compact, processing systems were integrated and devices for calculating the fees were developed, the device for calculating the fee was called charging unit (CHU). In order to meet the various needs of the car park owners and to allow free setting of the parking fee, the devices are designed. The introduction of EPS in Singapore has brought about an unprecedented realization of the application using the same onboard equipment in both EPS and ERP systems (application fields).

1. Introduction

The spread of Automatic fee collection system for collecting the traffic charges has become a global trend. In Japan Electronic Toll Collection (ETC) is now operating in major toll roads. The ETC is a toll collection system that allows the driver to pay the toll without having to stop the vehicle. The toll is collected from the IC card into the onboard equipment using radio frequency (RF) communication with the antenna installed on the toll plazas.

In Singapore the excessive traffic congestion at the Central Business District (CBD) became a social problem. This led to the adoption of a "road pricing system" in order to control the traffic volume by charging the vehicles going into the CBD area. This system is called Electronic Road Pricing (ERP) and is used for collecting the toll during the morning and evening traffic jam. For this system, in-vehicle units (IU) were supplied by MHI in 1998, more than 99% of the vehicles in Singapore are equipped with them. As a result, IU becomes social infrastructure in Singapore. In other words, Singapore presented an ideal environment for the application of IU to other fields. One of such fields was the development of Electronic Parking System (EPS), a charge collecting system in the parking lots. In EPS, the parking system has been realized by using the 10 digits numbers, called the specific IU labels memorized for each IU for vehicle identification.

In developing the EPS system, antennas were made smaller on the basis of the technologies obtained through ERP system so as to allow application to underground parking lots with limited installation environment, and a highly universal charging unit (CHU) that can conform to the requirements of car parks with various charging systems were developed.

2. Outline of EPS

(1) Features

The features of EPS are given below.

(a) Availability

The driver doesn't have to open the window to take a ticket or to pay the charge, and the vehicle can pass through the entrance/exit gates without having to stop. The driver doesn't need to prepare the cash (money) to pay.

(b) Flexibility of car park operation (management)

The car park owner or manager can flexibly change the parking charges table depending on their demands.

(c) Reliability

The RF communication and security technologies of ERP system have been used in ensure high reliability of the system.

(d) Service time (hours)

Since no need of handling tickets or cash at the entrance or exit gate allows non-stop operation, the processing capacity at exit can be drastically improved.

(The processing time per vehicle can be shortened to 3–4 seconds against about 15 seconds needed by the existent system.)

(2) System types

There are three types of EPS system as shown below.

(a) Access control (entrance/exit control) system

This system is installed in the car park for monthly subscribers, and is used only for checking the entrance and exit of vehicles, not for charging.

(b) Charging system

This system is installed in private car parks where the vehicles are charged according to the vehicle types and parking time.

(c) Free-flow charging system

This system utilizes the most of the EPS features, allowing non-stop charging. As in the case of ERP, in order to let the vehicles pass without having to stop, image processing system using camera are required so as to detect and catch the invalid vehicles, and to make the system a foul-proof system.

The developments for the aforesaid items (a) and (b) were carried out. As for item (c), the future trend in need will be thoroughly monitored and dealt with accordingly.

2.1 Access control (entrance/exit control) system

The access control system configuration is shown in **Fig. 1**.

(1) Operation at the entrance

(a) When the vehicle presence detector (loop coil) at the entrance detects a vehicle, the antenna radiates radio frequency.

(b) The antenna makes communication with the IU installed in the vehicle, and reads the IU label to check whether the IU label is included in the list pre-recorded in the antenna or host computer, and if the label is found to be included in the list, the barrier opens. The vehicle can enter the car park.

(2) Operation at the exit

The exit is also equipped with a vehicle presence detector (loop coil) and a barrier. The barrier opens when the vehicle presence detector detects a vehicle. The outside vehicles cannot enter from the exit because of the barrier.

The access control system has two modes: the stand-alone mode where the list of IU labels of the parking cars is recorded in the antenna and the on-line mode where the IU label list is recorded in the host computer that may be installed in the office. In the case of stand-alone mode, the IU labels are added to or deleted from the list recorded in the antenna for maintenance, according to the need, by connecting a maintenance computer. In the case of on-line mode, however, the maintenance of IU labels can be easily carried out using the host computer. The car park owners and managers can select the mode according to the scale of the car park, and can further install an antenna at the exit to allow flexible management of the car park such as detection of detention time, etc.

2.2 Charging system

The charging system configuration is shown in **Fig. 2**.

(1) Operation at the entrance

(a) With a vehicle detected by the vehicle presence detector at the entrance, the antenna radiates radio frequency.

(b) The antenna reads the IU label through communication with the IU installed in the vehicle, and transmits the IU label to CHU before opening the barrier.

(2) Operation at the exit

(a) With a vehicle detected by the vehicle presence detector at the exit, the antenna radiates radio frequency.

(b) The antenna reads the IU label through communication with the IU installed in the vehicle, and transmits the label to CHU.

(c) The CHU (host computer, depending on the system) calculates the parking fee of each vehicle from the parking time of the vehicle on the basis of the IU label transmitted by the antenna.

(d) According to the calculated fee, CHU issues charging command and it is transmitted to IU through the antenna.

(e) On receiving the charging command, the IU deducts the parking fee from the IC card.

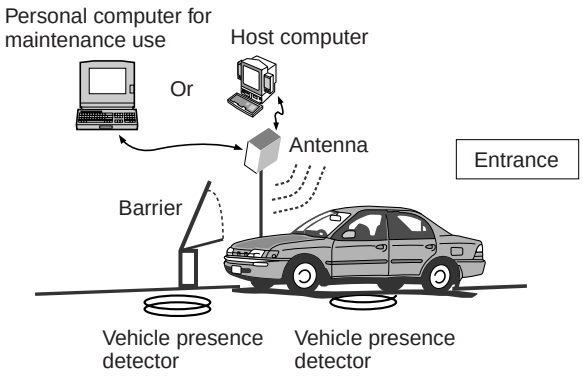

Fig. 1 Access control system

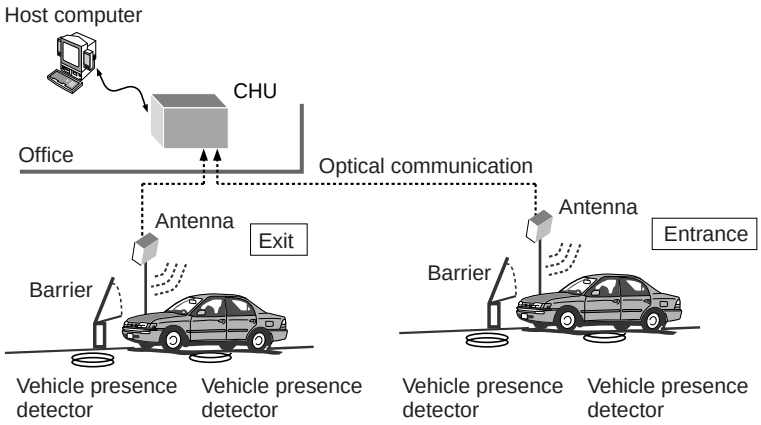

Fig. 2 Charging system

(f) The IU then inform CHU through the antenna that the parking fee has been deducted from the IC card.

3. Development of EPS

The development of EPS equipment is based on the technologies achieved through ERP. The ERP system has successfully realized the high-grade performances such as charging at 120 km/h and identification of invalid car at 180 km/h by advanced equipment and through complicated system configuration. **Fig. 3** shows the configuration of ERP system.

In the development of EPS, integration and miniaturization of ERP system functions were carried out, and the specifications required of a parking system were realized. On the other hand, compared with the low-cost existing tag system, EPS clearly makes difference not only in access control system but also in charging fee by using IU.

The devices of ERP system were functionally integrated to two types of devices, that is antenna and the other is CHU, with the devices configuration shown in **Fig. 4**.

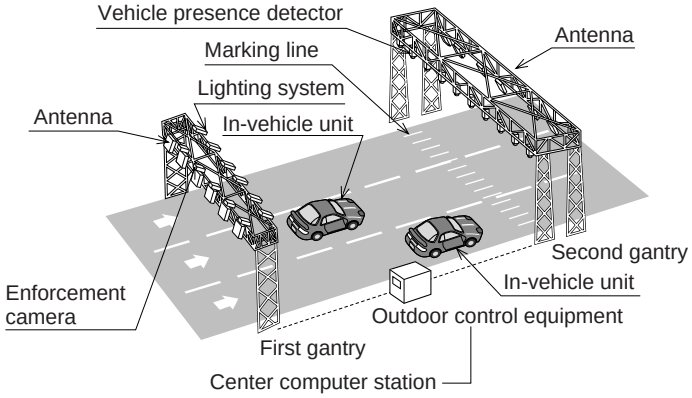

Fig. 3 ERP system equipment configuration

(1) Development of integral-type antenna

Antenna transmits radio waves to communicate data with IU using radio frequency communication.

The antenna function in ERP was only RF communication. The EPS antenna, however, was designed to be equipped with one-chip micro computer and memory and to have a built-in communication control function to allow access control solely by the antenna. Further, it also enables to build up a system of collecting parking fee from IC card by making connection with CHU.

(2) Development of CHU

The CHU was designed as a unit consisting of fee calculation and security units with integrated functions of parking fee calculation, encryption and decryption of processing data and vehicle control.

The development program for each device is described below in detail.

3.1 Development of integral-type antenna

Among the component machines of ERP system, the antenna, radio frequency communication unit (RFU) and a part of the antenna controller for preparing transmit data were integrated to the antenna.

(1) Antenna communication area

In ERP the radio-wave emission pattern was focused to the lane width direction in order to identify the vehicle, and a long communication area in the forwarding direction was formed as shown in **Fig. 5** in order to secure the communication time. On the other hand, there are a number of restrictions depending on the surrounding environment in the installation of antenna in a car park, such as the requirement of a wide communication area in the direction of lane width to cover an area equivalent to one lane by using a single antenna, the restriction in antenna

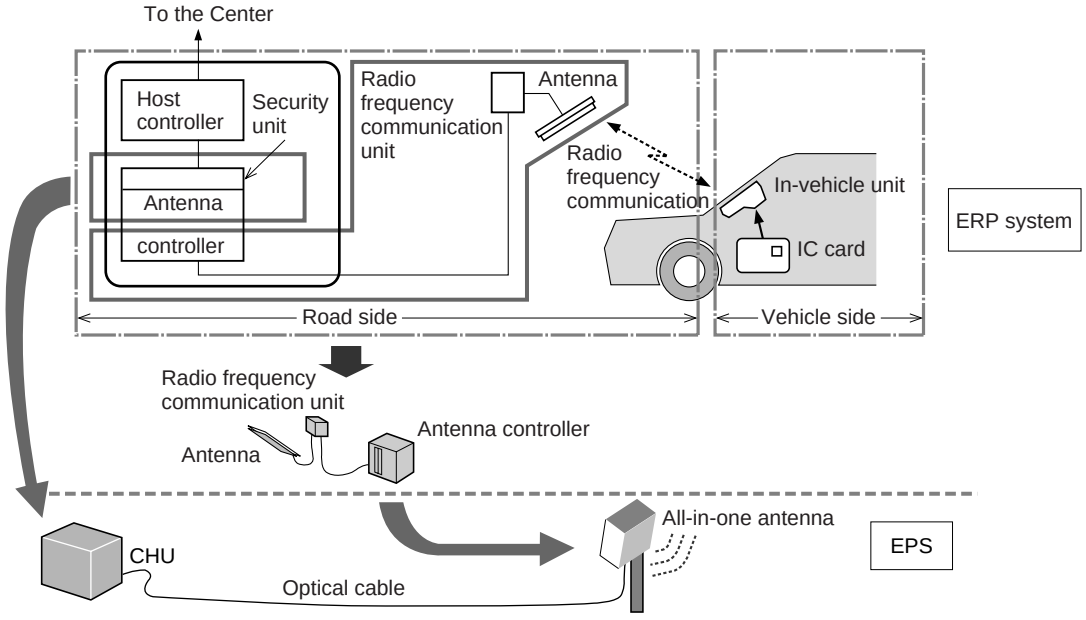

Fig. 4 Relation between ERP system and EPS system

Integration of ERP system machines (devices) led to the development of EPS system.

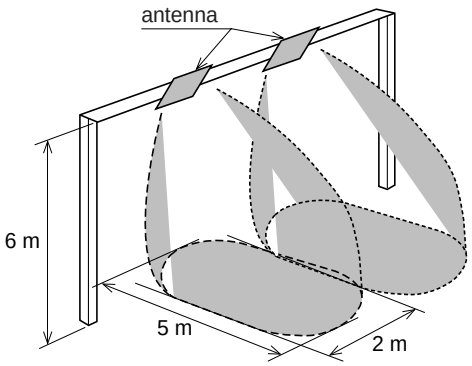

Fig. 5 Communication area of ERP

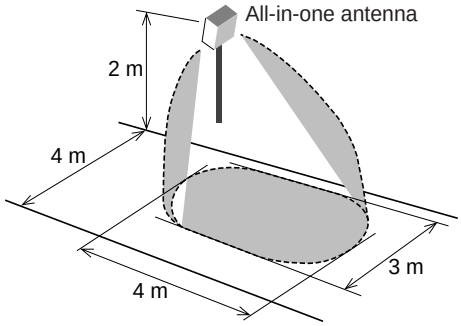

Fig. 6 Communication area of EPS

Fig. 7 Photograph of antenna

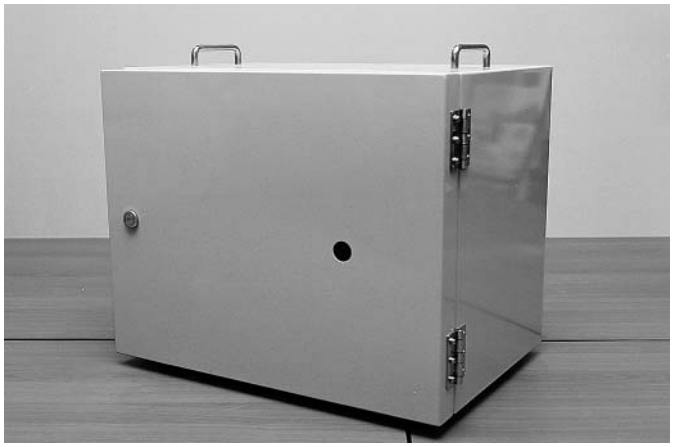

Fig. 8 Photograph of CHU

installation height in an underground car park and so on. Further, it is necessary to set the antenna communication area so as to secure the communication area even under restricted environment in order to make communication with the concerned vehicle while making no communication with the other vehicles.

With the aforesaid conditions taken into account, the communication area shown in **Fig. 6** was set, and the beam pattern of the antenna to satisfy the conditions was simulated in order to determine the antenna installation conditions. Further, the communication area was measured using the actual equipment, with the result found to conform to the design values.

(2) Antenna and radio frequency communication unit

In consideration of multi-lane control, the ERP system is equipped separately with antenna unit and radio frequency communication unit, because of an excessively large antenna in order to control the communication area. Thus, these units were miniaturized, and had their size and structure reviewed to enable them for indoor use.

(a) Antenna power level

Based on the simulation result of communication area, the transmission power level was reduced to optimum level and the high-frequency circuit was downsized.

(b) Antenna element

The antenna pattern was reviewed and optimized to satisfy the communication area in order to realize miniaturization.

(3) Antenna controller unit

In order to develop small-size antenna unit for car parks, the antenna controller unit was miniaturized and integrated in the following manner.

In ERP system, the antenna controller unit was a VME bus single-board computer, and was equipped with a large amount of RAM using a general-purpose CPU. This was integrated into a single-chip microcomputer capable of high-speed processing, and peripheral interfaces were added, leading to reduction in size by half. As for the single-chip microcomputer, the microcomputer with built-in flash ROM allowing easy exchange of software was selected to provide flexibility at the time of maintenance and alteration in specification.

Further, in the case of stand-alone mode, the all-in-one antenna was equipped with the input of vehicle presence detector and the control output of barrier to enable to build up the access control system without the help of the host computer.

3.2 Development of CHU

(1) Miniaturization

In order to realize miniaturization, the single-chip

microcomputer capable of high-speed processing was adopted. Further, the system was equipped inside with a flash ROM allowing easy exchange of software.

(2) Interface

The machines and devices are installed at different places in a car park. Especially the antenna units installed at the entrance and exit are often located away from the CHU installed at the office.

For this reason, the connection to the antenna was changed from the conventional metal-cable communication system to optical communication to ensure long-distance and speedy transmission.

(3) Function

The following two types of CHU function were prepared and various contrivances were made to meet diversified requirements of car parks.

(a) Type-1

This type of CHU is equipped inside with the function of vehicle control in the car park and charging table, and charges the vehicle driver by calculating the parking fee from the detention time inside the park. It can be easily introduced in a small-scale car park. Since the entrance/exit process are carried out only by CHU, it ensures high-speed processing.

(b) Type-2

This type of CHU charges the vehicle driver based on the data obtained by the host computer through vehicle control in the car park and by calculating the parking fee. This type enables different charging calculations simply by charging the host computer software and enables to build up a highly flexible system. Further, this system can meet with various other needs such as the addition of EPS function in an existing car parking system, and can be easily introduced simply by adding an interface function to EPS for the existing car park.

4. Conclusion

MHI launched the newly developed all-in-one, small-size antenna and highly universal CHU for EPS in the market in 2002, and various car parking systems (access control system, charging system) using these devices are being put into practical use by a large number of system integrators in Singapore. The EPS system, a highly convenient car parking system, is expected to spread rapidly in Singapore. MHI takes full account of the trend in market needs, and is determined to continue development on the free-flow charging system in addition to the access control system and charging system. In the future, MHI is determined to make efforts in developing the car parking system in Japan using the ETC on-board equipment on the basis of the ERP and EPS technologies obtained through the experiences in Singapore.

KOBE SHIPYARD & MACHINERY WORKS

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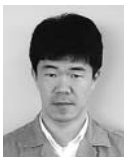

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