Radio Modules

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Abstract

In recent years the telecommunication using Portable Phones has been shifting from voice communication to data communication, typified by e-mail /Internet connection services.Further, it is anticipated that there will be an expansion in utilization of mobile phone networks as transmission lines for data communication, e.g. in "mobile data communication" for accessing the companies' databases from the outside of company in business use, and in data communication for realization real-time pickup/delivery management data systems in the transportation industry, etc.

In order to computerize vehicle interiors, in future it will be indispensable that on-vehicle date terminals access mobile phone networks. Our company has developed the card sized radio module built into the equipment,that is able to access both line-switching network and packet-exchange network.

1. Introduction

1.1 Background

In recent years, the voice-oriented portable phone market has attained maturity, the increase in new subscribers has begun to slow, and common carriers have attempted to expand new demand for nonvoice communication (data communication).

The portable phones supporting the i-mode service of NTT Mobile Communications Network Inc. (NTT-DoCoMo) have diffused so rapidly that more than four million portable phones have been sold in the year since their market release. Demand for data communication typified by electronic mail and Internet connection services is expected to grow further.

People who use data communications for business to access their company databases from outside and share information have increased needs for mobile data communication. In the transport industry, data communication is becoming vital for realtime handling of cargo collection and delivery management information. In the field of the Intelligent Transport Systems (ITS) expected to evolve in the future, implementation of services using the portable phone network will give impetus to the increase in demand for data transmission.

To implement the above services, Fujitsu TEN has developed a card-sized radio module that can be built into the equipment. This module is optimal for these applications and supports circuit switching method and single-slot packet method.

1.2 Radio Channel Control Method

The current radio circuit for the digital portable phone provides communication using the time division multiplex access (TDMA) method. As shown in Fig.1, this multiplex method is used to divide the time base into time slots of 6.6 ms each (separator on the time base: hereinafter, called a slot) and sequentially place three slots for three users to connect the circuit using the same channel (frequency) concurrently.

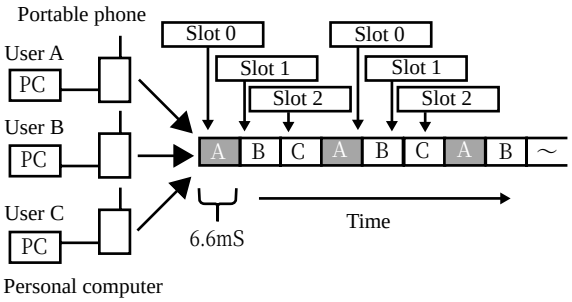

Fig.1 Time division multiplex access (TDMA) method (full rate)

For multiplexing, the data to be transmitted is compressed to one third of time; this method is called the "full rate method." In the metropolitan areas with high traffic rates, the half-rate TDMA method is used to compress data to one sixth of its time to enable six users to make calls concurrently.

1.3 Communication Method

Conventional voice and data communication is done using the circuit switching method. When communication starts, a channel and slot are temporarily fixed between the sender and receiver to reserve the radio circuit. After communication ends, the circuit is opened to enable it to be allocated to other users. This method deteriorates the data transmission efficiency of the circuit because each user occupies the radio circuit even when data is not being exchanged.

Fig.2 shows an example of the circuit switching method.

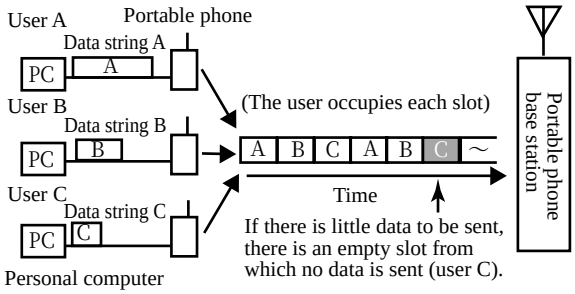

Fig.2 Circuit switching method

If there is little data to be transmitted and one slot is available, transmission is completed. However, user C continues to occupy the circuit and another user cannot use the circuit even if the slot becomes empty.

The data communication method by which data to be transmitted is divided into packets of 128 bytes each (packages with tags) for transmission is called the "packet switching method" (Fig.3). This method is now being used for portable phones.

In the packet switching method, the channel is fixed between the sender and receiver to connect the radio circuit. However, no slot is fixed and an empty slot is used to transmit the packet with the destination specified. This enables three or more users to share the radio circuit. During communication in which data is intermittently exchanged to respond to accesses like connections to the Internet, the efficiency of using the radio circuit is also improved. The packet switching method is provided with the single-slot packet (SSP) or

full-slot packet (FSP) service depending on the number of slots that can be used.

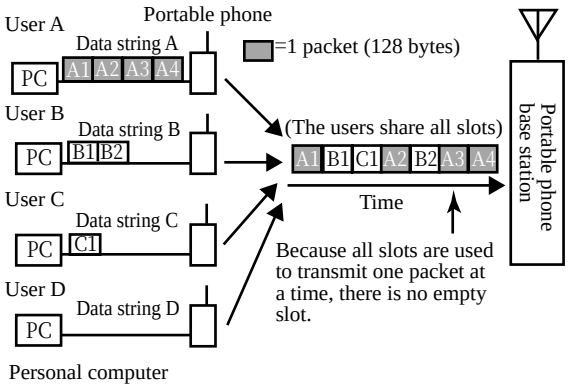

Fig.3 Packet switching method

As shown in Fig.4, SSP uses every third slot to transmit a packet and opens the slots for other users when there is no packet, as in the circuit switching method. FSP uses all empty slots to transmit a packet. The data transmission speed is 9,600 bits per second for SSP and up to 28,800 bits per second for FSP (9,600 bits per second x 3 when all three slots are empty). FSP is often used for business applications requiring high data transmission speed. The communication charge is higher for FSP than for SSP because it occupies more slots. Because SSP uses the same slot as a portable phone using the conventional circuit switching method, little hardware

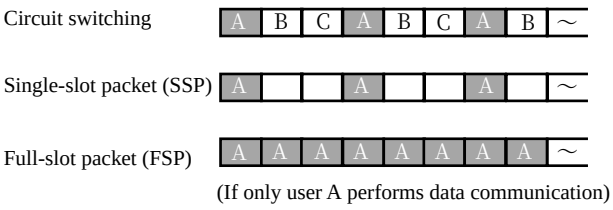

Fig.4 Difference between SSP and FSP

modification is required during design. However, FSP requires additional circuits and increases the hardware cost. The NTT-DoCoMo i-mode service uses SSP.

Comparing the switching methods in terms of the communication charge, communication is charged according to the entire communication duration from start to end regardless of the data transmission time in the circuit switching method as shown in Fig.5. In the packet switching method, generally, the meter-rate system is applied to charge communication according to the amount of data (number of packets) that has been transmitted. This method is more advantageous in terms of cost if data transmission is intermittent.

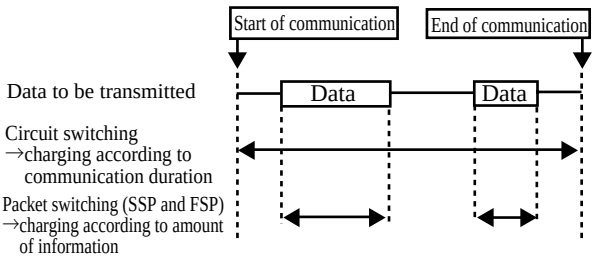

Fig.5 Communication cost

As listed in Table 1, the scope of data communication using the circuit switching and packet switching methods varies depending on the frequency of data communication and the amount of data. The packet switching method is suitable for data communication in which data is intermittently exchanged like electronic mail and Internet use.

2. Objectives of Development

Conventionally, when portable or in-vehicle data terminals are connected to a portable phone network to exchange information, the data terminals must be connected to an external equipment connector of the

Table 1 Scope of packet switching method

	Feature	Application
Circuit switching method	• One user occupies the circuit during communication. • The data transmission speed is constant regardless of the number of users who use the circuit concurrently.	• Continuous data transmission • Less frequent large-capacity data communication <For batch-processing type communication> FAX and large-amount data transmission
Packet switching method	• Multiple users share the circuit during communication. • If many users use the circuit concurrently, the data transmission speed decreases. • Regular connection requires no circuit connection time, when necessary. Busy state caused by channel shortage does not occur.	• Discrete data transmission and reception • Frequent small-capacity data communication <For interactive type communication> Electronic mail and Internet

portable phone via an external modem (data terminals may contain a modem) as shown in Fig.6.

This means that users have to mount and dismount the portable phone and connect and disconnect cable, which is inconvenient in a portable environment. The Mayday system, which automatically issues a rescue request in an emergency such as an accident, may not operate because the portable phone is left unconnected due to the inconvenience or is disconnected due to a shock.

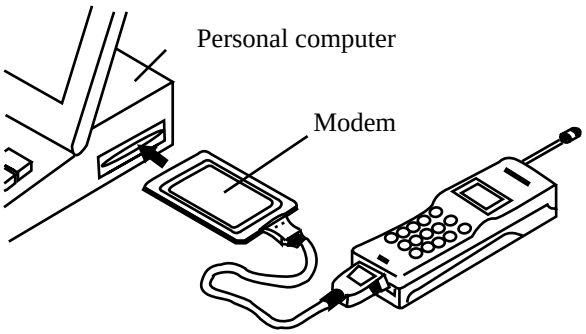

Fig.6 Conventional portable phone connection

An optimal device built into the equipment has been developed to achieve the following objectives:

(1) External size

A compact device whose external size is equivalent to that of industry standard radio modules PCMCIA TYPE III (85 x 54 x 10 mm: PC card size for notebook personal computers) was provided to facilitate the design of the information equipment. A thin, high-density printed circuit board and a thin plate were used to make the device light.

(2) Higher function

Orientation was toward data communication, and a modem (data adapter) was built into the device. This simplified the conventional system consisting of an externally connected hardware modem or a CPU incorporating a software modem. Also, this reduced the load on hardware and software in the data terminal and the components built into the equipment.

(3) Various communication methods

The circuit switching and single-slot packet data communication functions and voice communication function were incorporated to enable selection of the communication method that provides the lowest running cost based on the data contents and traffic that varies with the applications to be used.

3. Overview of Product

3.1 Block Configuration

Fig.7 shows the circuit block diagram.

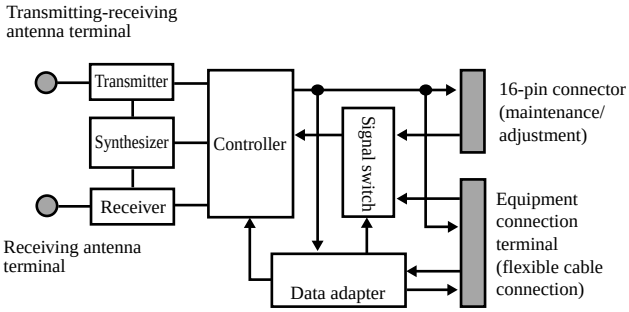

Fig.7 Circuit block diagram

In addition to the same controller and high-frequency sections (synthesizer, transmitter, and receiver) as a conventional portable phone, a modem (data adapter) was included to convert data transmitted to and received from the equipment connection terminal. A signal switch was provided to switch the signal input terminal for controlling the radio module externally instead of using the 10-key pad. A connector for external antenna connection was used for the antenna instead of a fixed whip antenna.

3.2 Interfaces

(1) Equipment connection terminals

A flexible cable was used for connection of the radio module and the equipment into which it is built to reduce the occupation ratio of the connector and connection cable and attain flexibility when routing the cable in the equipment. A general-purpose, 45-contact and 0.5 mm pitch flexible cable can be connected.

Table 2 gives an outline of the equipment connection terminal.

Table 2 Equipment connection terminal

Terminal type	Number of pins used	Remarks
Power	4	4.0V
Grounding	10	GND and including reserved terminal
Data transmission	8	AT command
Adapter control	6	Status display
Voice	4	Transmission and reception voice
Portable phone control	8	Reset and power control
Portable phone monitor	5	In-range/out-of-range and electric field display

After prior coordination with the designer of the data terminal equipment into which the radio module is built,

the signal contents for equipment connection terminal were considered based on the terminal specification used for Fujitsu TEN on-vehicle equipment so that the radio module can be used with various equipment.

The power system uses four individual pins for the power supply and grounding respectively, to prevent the voltage dropping during transmission.

The data transmission terminal supports serial communication (C-MOS level), and the modem control command conforms to the most common AT command specification.

A balanced output system is used for the reception voice system to reduce voice noise caused by grounding potential fluctuations triggered by changes in consumption current during transmission.

Because this module has no indicator, the display output terminals listed in Table 3 were set so that the status can be identified and displayed on the equipment into which the module is built.

Table 3 Display output terminals

Terminal name	Remarks
AREA	In-range/out-of-range of portable phone
PACKET	In-range/out-of-range of packet
ANT3	Electric field intensity (strong)
ANT2	Electric field intensity (middle)
ANT1	Electric field intensity (weak)

(2) Antenna connection terminal

Table 4 gives an outline of the antenna connection terminal.

Table 4 Antenna connection terminal

Parameter	Remarks
Characteristic impedance	50Ω
Voltage standing wave ratio (VSWR)	1.3 or less (DC to 3 GHz)
External dimensions	4.0(W)X4.5(D)X1.7(H)

An external antenna was used for the radio module antenna to increase the degree of mounting freedom based on the structure of the equipment into which the module is built. A small surface-mounting connector was used for the antenna connection terminal to reduce its occupation area in the radio module and the equipment into which the module is built and to ensure that the thickness of the product with the cable connected within 10 mm.

A transmitting-receiving antenna and receiving antenna can be connected to improve the receiving sensitivity through diversity reception.

(3) Terminal for adjustment and maintenance

A connector equivalent to the nonphone terminal standard for conventional portable phones was mounted to enable adjustment and maintenance of the radio module using the same facility as the portable phone.

3.3 Structure

(1) Shielded structure

Simplifying the structure is indispensable for providing the compact radio module. To avoid deterioration of the characteristics caused by oscillation of the high-frequency circuit and sneak of high-frequency power to the signal generator, the structure must be securely shielded. This module uses an H-type housing structure made of a glass fiber resin chassis, and the controller and high-frequency sections are completely separated by the cabinet.

Figure 8 shows the structure.

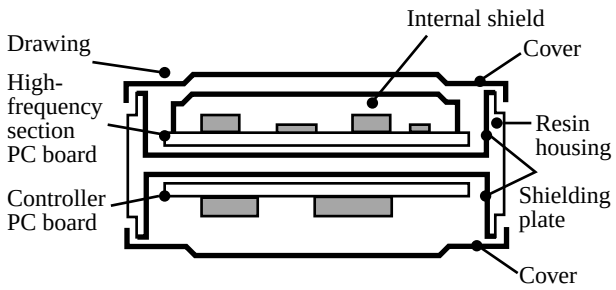

Fig.8 Mechanical structure

The PC boards were individually shielded and separated from each other by combining the shielding plate and plate cover case. An internal shield was also added to the high-frequency PC board to strengthen the shielding effect. The area of contact between the PC board and the shielding plate is a gold plated spring-like protrusion for contact between the shielding plate and the PC board and case. This causes the grounding potential between shielded components and at the PC board to be the same and provides sufficient shielding effect so that the electrical characteristics can be satisfied.

The high-frequency and control PC boards are single-sided boards with a ground pattern all over the solder side to reduce the impedance on the ground side of the PC boards. Stabilization was ensured, and the shielding effect between PC boards was improved to achieve a two-PC board configuration at a product

thickness of within 10 mm.

(2) Avoiding stress on PC board

Each PC board is connected by an interboard connector. The PC boards are not secured with screws but form a floating structure. This structure prevents solder cracks caused by mechanical stress on the connector and avoids reduction of the PC board mounting area because of the need for mounting screws.

(3) Material

A glass fiber polycarbonate resin chassis is used to improve the housing rigidity. The effects of external mechanical stresses such as drops or torsion on internal components is reduced to improve the reliability.

A thin SUS shielding plate 0.1 mm thick was used to minimize the limit on the component mounting height.

Because the material is thin and may crumple due to drawing, the module was designed to optimize the shape and position of drawing.

The pressed 0.3 mm SUS cover has convex drawings to ensure its strength and improve the cabinet rigidity.

(4) PC board

A 6-layer ALIVH(*1) PC board was used to expand the patterns with all-layer Inner Via Hole (IVHs). This enables connection between any adjacent internal layers to ensure high-density wiring and high-density packaging and provide compact and light PC boards.

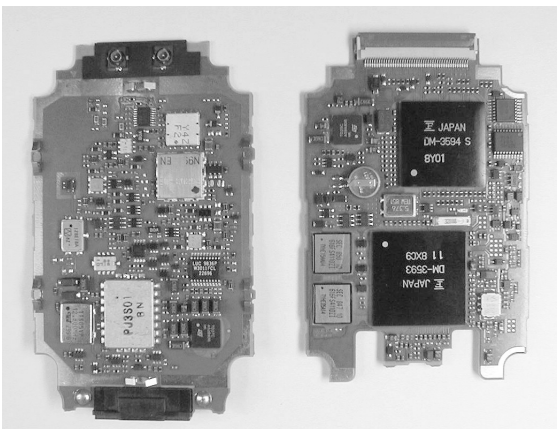

Fig.9 Circuit board

3.4 Major Specifications

Table 5 lists the major specifications of this module.

4. Application to Products

This built-in radio module can be applied to various products. Especially, ITS is one of the fields Fujitsu TEN is attempting to develop, and a wide variety of applications in this field can be considered.

Table 5 Major specifications

Parameter	Specification
Applicable circuits	Digital portable and automobile phone circuits Packet communication circuit
Transmission method	Digital automobile phone system Packet mobile communication service (DoPa)
Communication speed	Packet communication: Up to 9,600 bps Data communication: Up to 9,600 bps FAX communication: Up to 9,600 bps (ECM)
DTE-DCE communication speed	115.2k,57.6k,38.4k,19.2k,14.4k,9600 4800,2400,1200bps
External dimensions	About 85 (W) x 54 (D) x 10 (H) mm
Weight	About 63 g
Power supply	DC 4.0V ±10% Supplied with flexible cable from external equipment.
Consumption current	370 mA (talking)
Ambient environment	Operating temperature range: +5 to +45℃ Storage temperature range: -20 to +60℃
Control command	Conforms to AT command.
Technical standard-compliance certification	Certification number：A99-0052JP AJ99-1019
ARIB connectivity confirmation	Confirmation number：DA1995FJT004AA

4.1 Application to Mayday System

The Mayday System ensures that in a car accident or other trouble, GPS location data and emergency information are transmitted from the in-vehicle terminal to the center so that an ambulance, police, or tow truck can be sent to the scene immediately. In the United States and Europe, this service has already been started, and in Japan, this service is also being planned. The portable phone network, which has a wide service area and is relatively stable is a likely means of transmitting this emergency information to the center. The phone module is built into the in-vehicle terminal to facilitate construction of the system. Unlike the method for connecting a portable phone on hand to the in-vehicle

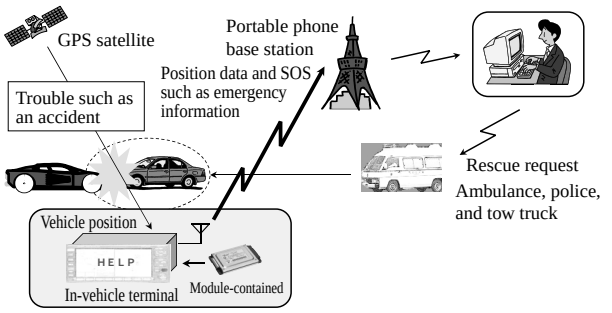

Fig.10 Example of Mayday System

terminal, a sound circuit connection is ensured. The system can always be operated when necessary and is the most suitable system for assuring the safety of the customer.

4.2 Application to In-Vehicle Information Service

The in-vehicle information service provides useful driver-requested information to the in-vehicle data terminal (car navigation) in real time through the radio. The portable phone network is also the most suitable means for transmitting this information. Currently, Mobile Network (MONET) of Toyota Mobile Corp. provides this service and the navigation system using the i-mode service is also commercially available. The radio module is built into the in-vehicle data terminals to ensure that trouble during operation is eliminated, operability in the vehicle is improved, and the device is compact.

4.3 Application to Hand-Held Terminal

It is becoming common for transporters to use hand-held terminals (HHTs) to accumulate cargo collection and delivery information from the customer by reading the bar code on the tags or through 10-key pad input.

Conventionally, when the collection and delivery car returns to the collection and delivery center, batch processing is executed to transfer HHT information to the host terminal at the center. This processing may delay information and cannot respond to inquiries from the customers in real time.

This radio module that has now been developed was built into the HHT to enable the transfer of cargo collection and delivery information from the customer to the collection and delivery center and the realtime identification of cargo status. This ensures immediate response to the inquiries from the customer and improves the service.

Fig.11 Example application of product

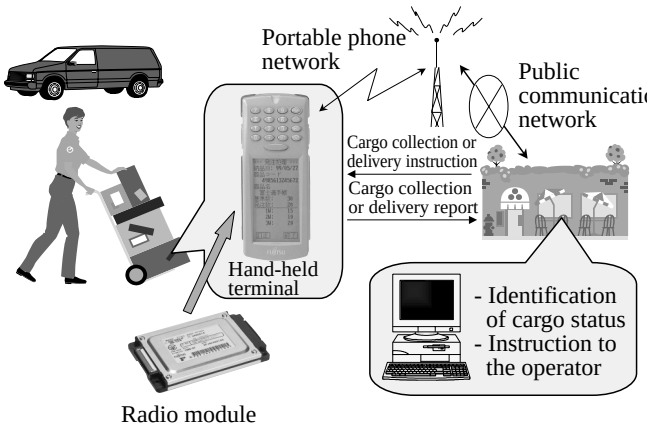

Fig.12 Example transportation management system with HHT

Fig.11 shows an example of an HHT containing this radio module, and Fig.12 shows an example of an HHT system.

5. Future Outlook

As described above, as a first step, the currently commercialized built-in product is applied to a system that has conventionally been realized by connecting an available portable phone. Compared to the conventional method, the product is smaller and has improved operability and portability.

As the next step, the product is expected to evolve into the following systems that are viewed as new demands:

(1) Vehicle operation management

The product is installed on buses, trains, and transport trucks to enable realtime monitoring of the vehicle's status at the center so that the identification of operation status and the control of vehicle allocation are accurate. Conventionally, the operation status is identified and vehicle allocation is controlled through a special radio, but information was intermittent. Realtime packet communication will enable provision of more carefully devised services.

(2) Vending machine management

The product is built into the vending machine to enable realtime control of product inventory. Because the inventory and equipment status can be identified without the need to go to the relevant locale for confirmation, an out-of-stock or failure state can be immediately remedied to ensure efficient replenishment and maintenance planning. Conventional systems use underground cables. The module is built into the vending machine to enable construction of a new system without needing to rewire after relocation, which will

lead to reduction of cost.

In addition to evolution into application to in-vehicle equipment such as the previously described Mayday System and in-vehicle data terminal, the module can evolve into the private fields where there has been a problem with its practical use. For example, we can anticipate using a built-in module that can access the portable phone network simply via normal terminal (small personal computer) operations. This would represent a step forward in mobile communications using a small personal computer, whose portability has been doubtful, and whose use has not spread.

The module is built into the equipment to enable the user to connect to the portable phone circuit without extra operations as before and to access the huge information sources on the network through the data terminal. These features can be viewed as requisites for the terminal products of the future information society, and application of the module to a wide variety of products is expected.

To suit these applications, Fujitsu TEN is now promoting development of a card-type radio module that is equivalent to the thinner PCMCIA TYPE II (85 x 54 x 5 mm) card.

In the future, smaller and thinner modules will be required to increase the degree of freedom of building it into the equipment. In Europe and Asia, a system that enables the same telephone number to be used on multiple portable phone terminals by entering ID information into a SIM card (small IC memory) and inserting it is being used for the GSM portable phone. A built-in module with the capabilities of this system is also expected to be in common use. The company will promote development of radio modules that satisfy the market.

6. Problems

6.1 Performance

With the increase in products with built-in radio modules, unexpected problems such as environmental conditions and noise interference are expected to occur. The performance must be further improved to prevent interference from the environment and the equipment into which the module is built. Also, the application range of the radio module must be expanded.

6.2 Initial Cost

A radio module is built into the in-vehicle data terminal to enable use of the portable phone network without the need to connect to the telephone set. In the current stage, however, the following cost problems must be solved.

When the radio module is built into the in-vehicle data terminal, a circuit contract with a common carrier (NTT-DoCoMo) must be made separately from the one for using the portable phone outside the vehicle because the telephone set is fixed. The initial costs such as charges for the circuit contract and communication are required. To solve this problem, in the United States, the charge for the contract has been falling because of the Mayday system. In Japan, NTT-DoCoMo is providing automobile phone owners with a one-number, multiple-terminal service (Selecphone(*2)), which enables use of one telephone number for terminals for up to three automobile phones used inside the vehicle and portable phones used outside the vehicle.

In the future, when services such as the Mayday system start, the circuit contract conditions suitable for systems containing the radio module will be established based on solutions to these problems.

A simplified and compact device made by building in a radio module may make it advantageous in terms of overall system cost to enable absorption of the initial communication cost. The entire system cost must be considered.

7. Conclusion

The above is an overview of a new radio module that has been developed. In the future, the demand for data transmission using the portable phone network is expected to expand in in-vehicle applications and in various other fields. This card-sized module will be able to satisfy these needs in a broad range.

We express our deep gratitude to the persons at the Product Planning & Design Departments, Mobile Radio Terminals Division of Fujitsu Limited and Engineering Department 2, Fujitsu Tohoku Digital Technology Limited who guided us in commercializing this module.

Reference

Tsukamoto et al.: Preparation for ITS Age
Fujitsu TEN Technical Report, Vol.16 No.1 (1998)
NTT DoCoMo Technical Journal Vol.7 No.3

*1 Any Layer Via Hole (ALIVH): Registered trademark of Matsushita Electronic Components Co., Ltd.

*2 Selecphone: Registered trademark of NTT Docomo

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