Ultra Small and Multifunctional 400-MHz Band Portable Two-way Radio

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As business activities advance, transactions have become more diversified and complex. Consequently, demand is increasing for the ability to quickly get and send necessary information from anywhere. The focus in the business use of wireless communication is shifting from vehicles to people. This has created a need for smaller portable two-way radios. To reduce size, developing smaller circuit modules and more precise mounting technology, while reviewing mechanical structures is necessary. In addition, users are demanding additional advanced features, such as digital code squelch (DCS) and selective call (sele-call) functions.

To satisfy these needs, Fujitsu TEN has developed a portable two-way radio (Series 76) for business use. During its development, our aim was to achieve the smallest size two-way radio in this market, while providing more advanced features.

The following is an introduction to the features of the Series-76 portable two-way radio. Detailed are the emphasized points in its design, focusing on the newly developed techniques. These techniques include the following: the bare chip mounted multi-chip module the heterogeneous material used in the molding case for size reduction; and the sele-call function for "efficient communication."

1. Introduction

Recently, the use of mobile communication has increased. The growth in demand is particularly high among medium and small-sized businesses. These businesses need mobile communication to support the activities of their in-field staff, who work more out of the office. In addition, this technology is necessary to facilitate and streamline the work of transportation and security personnel who may require urgent instructions and responses.

Table 1 lists a summary of the most widely used mobile communication systems that are currently available. These mobile communication systems are different in various points, such as in service area, communication method, radio operator license requirements, and communication charges. Customers select the appropriate systems that meet their needs.

Table 1 Comparison of mobile communication systems used for business

	Private			Public
	Simplified radio communication system	Various business-use radio communication systems	MCA/JSMR	Mobile (portable or car installed) telephone
Number of radio stations (unit: in ten thousands) (percentage to the number at the end of 1994)	75 <+0.7%>	178 <+2.1%>	88 <+6.5%>	1,240 <+110.5%>
Assigned channels	44 channels	–	2040 channels	4060channels × 2
Data to be transmitted	Voice	Voice and other data	Voice and other data	Voice and other data
Service area	Specific area (small)	Specific area (small to medium)	Specific area (small to medium) * A control station must be near the place of use.	All over the country * A control station must be near the place of use.
Communication mate	Only business staff	Only business staff	Only business staff	All wire/radio communication subscribers
Degree of interference	Medium to high	Low	None	None
Communication method	Broad-casting or individual communication (unidirectional)	Broadcasting or individual communication (unidirectional)	Broadcasting or individual communica-tion (unidirectional)	One-to-one communication through telephone number specification (bidirectional)
Radio operator license	Unnecessary	Necessary	Unnecessary	Unnecessary
Radio station license	Necessary	Necessary	Necessary	Unnecessary for users
Communication charge	None	None	Medium	High
Equipment cost	Low	Low	Medium to high	Users incur low charge because of rebates from carriers.

(As of the end of 1995)

Most medium and small-sized businesses only need voice transmission in a relatively narrow service area as features of their mobile communication system. Simplified radio communication systems are widely used for its benefits, such as low cost, no special license is required, and broadcasting is possible, among others.

However, only a few frequencies are assigned to simplified radio communication. The demand in the market cannot be satisfied. Multiple users are required to share the same frequency and this causes serious radio interference problems, especially in large cities. Radio station operations are hindered at this present condition.

The Series-76 portable two-way radio for business use was developed by Fujitsu TEN to support the simplified radio communication system and various business-use radio communication systems. To address the above mentioned radio interference problems of simplified radio communication systems, this two-way radio has both conventional tone and digital squelch functions as standard features. (The first use of a digital squelch function was in the series-71 business-use car-mounted radio.) Furthermore, this two-way radio has a digital code squelch (DCS) function as a standard feature, a first for two-way radios for Japanese market.

For size reduction, an overall review of the structure, circuits, and components was conducted. After this review, we were able to successfully develop the smallest two-way radio in the industry. In addition, this two-way radio has a splash-proof structure (JIS C0920 protection class 4) for outdoor use. Use in light rain is possible.

2. Outline of the series-76 tow-way radio

To make this portable two-way radio appropriate for use in stadiums, concert halls, and harbors by transportation crew and security staff, special efforts were made to reduce size and weight. Both the size and weight of this two-way radio were reduced to half of all currently available products in the market. In addition to being small and light, this radio comes with advanced features. For example, all models of this two-way radio are equipped with the sele-call (selective calling and communication) and DCS functions. Furthermore, this two-way radio is waterproof (splash proof). In addition, overall reliability was improved. Moreover, after reviewing and improving the structure and components, we were able to reduce the cost while offering such advanced features.

(As of the end of 1995)

2.1 Features

(1) Small size
- Size: 107 mm height × 54 mm width × 30 mm depth (assuming that the type of battery pack is S)
  Size and weight were reduced about 45% and 55% of conventional products, respectively.

(2) Advanced functions
- The sele-call function is a standard feature on all Series-76 models.
- A DCS function is a standard feature on all Series-76 models.
- A splash-proof structure (JIS C0920 protection class 4) is used.

(3) Settings are electronically adjusted
- All parameters that relate to transmission and reception frequencies, and other functions, can be externally set and adjusted from a PC using serial data. Thus, disassembly at adjustment or setting is no longer necessary.

(4) Highly reliable design
- A press-fit fixed screw SMA connector is used for antenna connection to reduce the risk of loose or poor contact in the antenna connector section.
- Temperature and humidity environmental tests, dielectric strength tests, and thermal shock tests were repeatedly conducted. The results proved that this Series-76 two-way radio is high reliable and can withstand harsh environment conditions.

(5) Affluent accessories
- A two-pocket quick charger with a refresh function is provided. (Fully charge an S-type battery pack within about 1.2 hours.)
- Two types of rechargeable battery packs having different capacities are provided. Either type is compatible for both 5- and 1-watt models (Table 2).

Table 2 Specifications of the rechargeable battery packs

		Battery pack L	Battery pack S
Battery type		Nickel-hydrogen secondary battery	
Voltage/capacity		7.2V / 1800m AH	7.2V/850mAH
Life	5-watt model	About 11 hours	About 5 hours
	1-watt model	About 17 hours	About 8 hours

This two-way radio uses nickel metal hyride battery as its built-in cell. Nickel metal hyride batteries have the following advantages: A large current is available at 5-watt transmission; its capacity is greater than nickel-cadmium batteries; and its environment hazard is low.
- A dry cell pack is provided to permit the two-way radio to continue running with six LR6 (AA-size) dry cells in emergency cases. (The 1-watt model can continue to run for about 5.5 hours if alkaline dry cells are used.)
- A splash-proof speaker and microphone are also provided.
- A short antenna is provided to prevent obstruction to operations (only for limited frequency bands).
- A leather case with a shoulder strap is provided.

Figure 1 shows the accessories.

Figure 1. Model 76 portable radio and accessories

2.2 Functions

Table 3 lists a summary of the functions of this two-way radio. All models of the Series-76, including both simplified and business-use models of the radio communication system, have a sele-call function as a standard feature. This function made by Fujitsu TEN is a first for portable two-way radios. Furthermore, the Series-76 two-way radio supports pager mode. When the opeerator cannot respond to incoming calls, pager mode can be used to enable terminating-tone reporting, sound muting, and elapsed time displaying for reception waiting

Addressing the radio interference issue that is involved in simplified radio communication systems, which is now a serious problem in urban areas, is necessary. This two-way radio has both conventional tone and digital code (DCS) squelch functions. As mentioned above, this is the first time this feature has been used in two-way radios for Japanese market made by Fujitsu TEN. The DCS function identifies users by 83 digital codes. This function became available because of a recent restriction relaxation.

Of the above signaling functions, newly adopted functions are the sele-call and DCS functions for simplified

radio communication systems. To keep compatibility between portable and car-mounted two-way radios, minor changes were made to the design of the conventional Series-71 car-mounted two-way radio.

Table 3 Summary of functions

Function	Explanation	Availability for business-use radio communication	Availability for simplified radio communication	Remarks
Trainning time-out-timer	10 to 180 seconds in 10-second steps	°	°	
Tone squelch function	Support for A tone, B tone, cross tone, and one-side tone	°	°	
DCS function	Support for 83 codes specified in RCR standard	°	°	☆
Sele-call function	Selective calling and communication	°	°	★
	Group call function	—	°	☆
Pager function	The elapsed time of reception waiting is also displayed.	°	°	☆
Digital squelch function	Map code = 16, user code = 128	—	°	★
Squelch monitoring function	The items to be disabled can be specified.	°	°	
Compandor function		°	°	★
Water-proof structure	Splash-proof structure (JIS C0920 protection class 4)	°	°	☆

Symbol ☆ means introduced for the first time in two-way radios of Japan by Fujitsu TEN. Symbol ★ means introduced by Fujitsu TEN for the first time in portable two-way radios.

2.3 Rating

Table 4 lists the rating and performance of the FTP40-576AT and FTP40-176AT, which are typical models of the Series-76 two-way radio for business-use.

Table 4 Rating and performance of FTP40-576AT and FTP40-176AT radios

Frequency range	360 to 470MHz
Modulation type	F3E, F2D
RF output power	5W (FTP40 to 576AT) 1W (FTP40 to 176AT)
Number of channels	Up to 8
Antenna impedance	50Ω
Channel separation	12.5kHz
Communication method	Unidirection communication
Oscillation method	Using a crystal-oscillator-controlled synthesizer
Modulation method	Variable-reactance direct modulation
Frequency error	±3×10-6
Frequency modulation	Within ± 2.5 kHz
Transmitter signal-to-noise ratio	28 dB or higher (for 60% modulation on 1-kHz signals)
Standard modulation input	-46 dBm (for 60% modulation on 1-kHz signals)
Reception method	Double-superheterodyne
Reception sensitivity	-5 dμ or less (12 dB SINAD)
Adjacent channel selectivity	60 dB or higher
Spurious sensitivity	55 dB or higher
Receiver signal-to-noise ratio	30 dB or higher
Receiver maximum voice output	0.5 W or higher
Power supply voltage	7.2 VDC ±10%
Current consumption (at power-supply voltage of 7.2 VDC)	Transmitting: 3.0 A or less and 1.5 A or less for the 5-watt and 1-watt models, respectively Receving: 200 mA or less (at the rated output voltage) Stand-by: 70 mA or less
Battery life (assuming that the ratio of transmitting; receiving; stand-by 1:1:18)	Battery pack L: About 11 hours and 17 hours for the 5-watt and 1-watt models, respectively Battery pack S: About 5 hours and 8 hours for the 5-watt and 1-watt models, respectively
Operating temperature range	-10 to +50°C
Dimensions	54 × 107 × 30 mm (assuming battery pack S)
Weight	About 280 g (assuming battery pack S)

3. Design points

3.1 Size reduction

To achieve size reduction, the following points when designing this two-way radio were emphasized:

(1) Use of the multichip module
To reduce size, the transmission and reception audio circuits, MSK modem circuits, electronic variable resistors, and a D/A converter were integrated into one module. The installation area is about 40% of conventional modules.
For details of this module, see Section 3.2.

(2) Use of a multilayer PC board
This two-way radio uses a six-layer PC board, which is 1.2 mm thick, as its main PC board. Thus, high density mounting is achieved. For the front operation panel, a polyimide flexible PC board is used. In addition, the operating section, display section, joint to the main PC board, part of the transmission and reception audio circuit are integrated into one component to minimize dead space for interconnection.

(3) Use of smaller surface mount devices
To achieve size reduction and further automate the manufacturing process, the percentage of surface-mounted devices was considerably increased when compared with conventional products. Simultaneously, the TCXO, helical filter, MCF, and other components, which take up a large amount of space, were replaced with smaller surface-mounted types of components. The newly developed multichip module is also surface-mounted using a newly developed surface mounted connector.
Figure 2 shows the main PC board of this two-way radio.

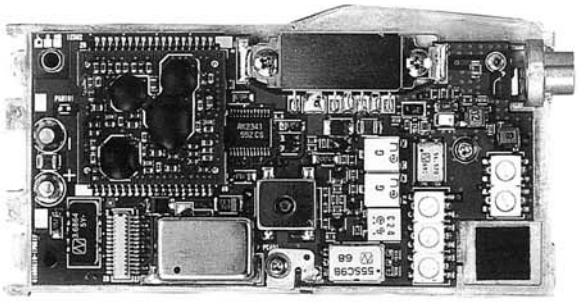


Figure 2. Outside view of main PC board

At present, at least about 97% of all devices are automatically mounted onto the PC board.

(4) Review and simplification of circuits
Conventionally, the automatic power control (APC) circuit in the transmission section controls the transmission power output. The collector current flowing in the transmission power amplification circuit, which consists of transistors, was controlled. However, this method required that transistors in the current control section have a relatively large allowable dissipation. This hindered size reduction. To solve this problem, a RF power amplification module of the MOS-FET type was used. The transmission power is controlled with the gate voltage. Thus, the circuit was simplified and made smaller.
For the battery voltage drop alarm circuit, conventional products use a low-voltage sensing IC or similar means. This two-way radio uses a one-chip microcomputer built in the A/D converter. This allows voltage drops to be detected by software and reduces the number of components.

(5) Use of a heterogeneous material for the molding case
This two-way radio uses a heterogeneous material for the molding case to reduce the number of components and make the mounting space of the internal device larger. When designing the molding case with heterogeneous material, reducing cost and creating a splash proof structure were emphasized. Size reduction was not given emphasis. The details are discussed in Section 3.4.

3.2 Multichip module

3.2.1 Features

We succeeded in developing a multichip module that is 40% smaller than conventional modules by taking advantage of bare chip mounting technology. We also succeeded in achieving high reliability to withstand harsh environmental conditions, assumed for portable and car-borne units, by optimizing materials and production conditions. Furthermore, we developed a connector of the surface-mounted type to simplify the process and reduce component costs. In this way, we succeeded in reducing costs by 15% when compared with generally-available modules by putting some key components into in-house manufacturing processes.

3.2.2 Specification

Table 5 lists the main specifications of this module. Figure 3 is a block diagram. Figure 4 shows the exterior of this module.

Table 5 Main specifications of a multichip module for communication equipment

Size	28 × 28 × 5 (mm)	
Built-in circuits	Transmission and reception audio circuits, among others	
Devices to be mounted	4 bare chips, one quad flat package (QFP), 51 other chip devices, and 2 connectors	
PC board	4 layers, 0.8 mm thick, electrolytic gold plating, minimum pattern width of 0.15 mm	
Reliability	Thermal shock test	Switching between -40°C and 125°C, 1000 or more cycles
	High temperature and high humidity bias test	85°C and 85%, 1000 or more hours
	PCT	120°C/2 atm, 96 or more hours

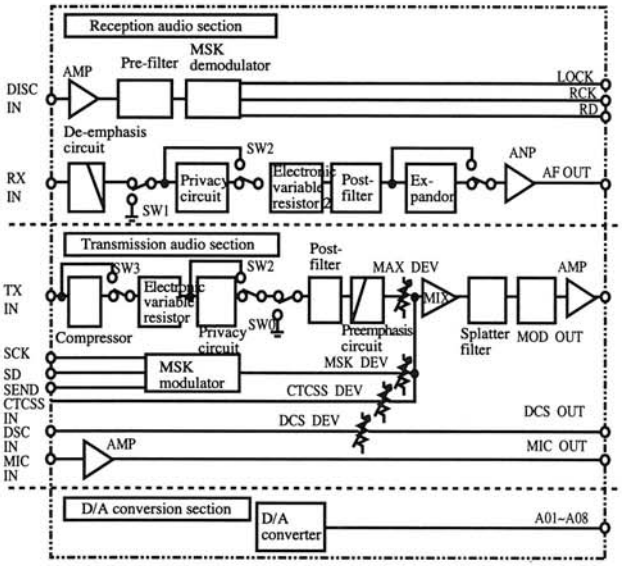


Figure 3. Block-diagram of multi chip module for two-way radio

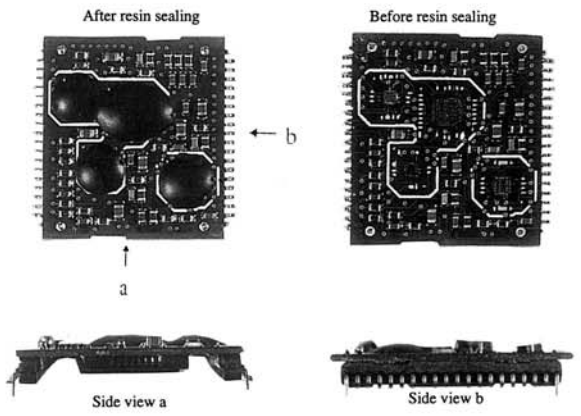


Figure 4. Outside view of chip module for two-way radio

3.2.3 Component engineering

This section explains the component engineering that was used.

① Highly reliable bare chip mounting on the resin PC board

The developed multichip module uses a resin PC board, which is relatively inexpensive when compared with ceramic PC boards. While keeping this cost efficiency, we also achieved high reliability to permit the multichip module to be used in cars. To achieve high reliability, increasing the bonding performance at individual points between the resin PC board and bare chips was necessary. We attempted optimization as shown in the "points of development" column in the following flow chart:

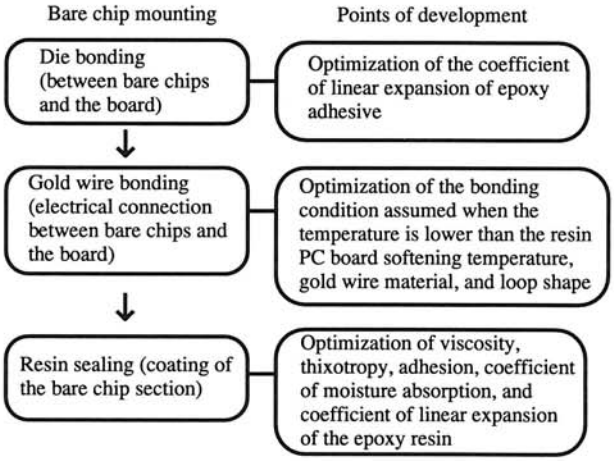
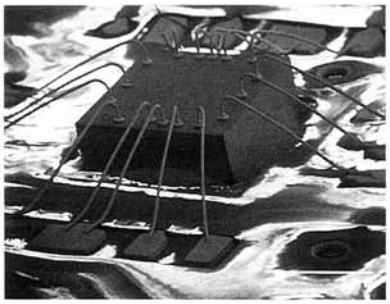
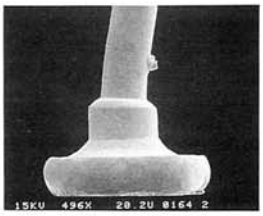


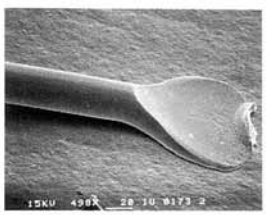
Figure 5 shows the bare chip mounting state and bonding section.

Photograph of the entire SEM





Bare chip side



PC board side

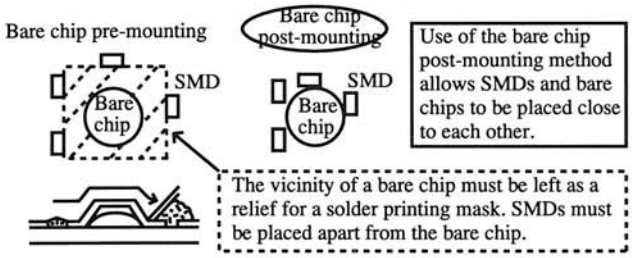
Figure 5. State of bare chip mounting and bonding point

② Using the bare chip post-mounting method to allow bare chips to be mounted together with surface mounted devices

We achieved high-density mounting of surface mount devices (SMD) and bare chips. Two methods of mounting exist: the bare chip pre-mounting and post-mounting methods. In the bare chip pre-mounting method, bare chips are mounted when SMDs are mounted. In the bare chip post-mounting method, bare chips are mounted after SMDs are mounted. We decided to use the bare chip post-mounting method to achieve high-density mounting. A new technique for bare chip post-mounting was developed and made available for mass production. Figure 6 outlines the bare chip post-mounting method.

③ In-house manufacturing of connectors and gang reflow soldering

We developed a multichip module and a suitable connector of the surface-mounted type for it. The connector was put into in-house manufacturing processes. Figure 7 shows the specifications and exterior of the connector.



[Points of development of the bare chip post-mounting method]

Subject	Points of development
Preventing the bonding pad from being contaminated	Improving the solder material and optimizing reflow and wash conditions
Achieving the sufficient resin sealing accuracy	Optimizing the viscosity and thixotropy of the material, developing the exhauster, and optimizing the exhaust condition

Figure 6. Bare chip post-mounting method

We also decided to perform gang reflow soldering on through-hole leads at both ends of the connector together with the surrounding SMDs, to simplify the processes.

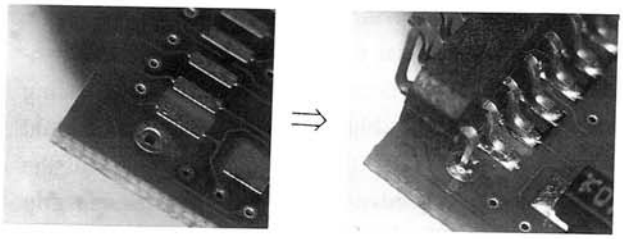
[Specification of the in-house, manufactured connector]

Material	Phosphor bronze pins, PPS-molded
Pitch	1.27 mm
Co-planarity	0.15 mm

[Exterior]

[Characteristics]
- With positioning lead
- Independent type
- Vertically symmetric shape
- Reflow heat resistant
- Inserting the mold, forming the lead, and cutting-off are performed by in-house processes.

[Gang reflow soldering of the leads]



Before solder paste printing

After solder paste printing and reflow processes

Figure 7. Connector for surface mounting

3.3 Structure

To reduce the size of portable two-way radios, the mechanical structure had to be simplified. Portable two-way radios must assure stable operation without raising PLL circuit howling, transmission circuit oscillation, and RF feedback problems. To assure stable operation, a mechanically durable and reliably shielded structure was required.

This two-way radio uses an aluminum die cast chassis, which itself has a shielded-case structure. In addition, we reviewed how to layout and fix the devices on the PC board. We succeeded in making this two-way radio assure stable performance with a simple structure.

We added a shielding capability to the flexible PC board holder and improved the method of fixing controls. The structure of this two-way radio was considerably simplified. For example, the number of screws per unit was greatly reduced, from 46 screws in conventional two-way radios to just eight. Details of the front case, which is related to the structure of the operating section, will be discussed in Section 3.4.

We also considered maintainability. When the two-way radio becomes faulty, both the main and flexible PC boards can simply be replaced by using a screwdriver.

3.4 Heterogeneous material of the molding case

To achieve the primary three design objectives of this portable two-way radio (i.e., size reduction, splash-proof structure, and cost reduction), using heterogeneous material for the molding case was indispensable. The material is fabricated through one-piece molding of hard resin and thermoplastic elastomer.

Heterogeneous material molding is one kind of one-piece molding. Hard resin, such as ABS and polycarbonate, and thermoplastic elastomer having rubber elasticity are subjected to heat fusion in a mold. Then, they are molded into one piece. This method allows the characteristics of individual materials to be utilized as functions in one component.

Two methods of using an injection molder to mold the heterogeneous material exist: insert molding and two-color molding. We decided to use the insert molding method because it has high flexibility, in terms of mold structure. High flexibility was necessary to fulfill the primary design objectives and to give the outside grip section of the elastomer a non-slip effect and improved ergonomic feeling. If two-color molding is used, the mold structure becomes too complex. Figure 8 outlines the structure of the heterogeneous material of the molding case used in this portable two-way radio.

The shaded areas in Figure 8 are made of thermoplastic elastomer. Other areas are made of hard resin.

To achieve sufficient size reduction and splash-proof performance, thermoplastic elastomer was used for all components with shapes that were complex in conventional products. For example, thermoplastic elastomer was used for the button and periphery packing areas, speaker, microphone, LCD opening, control section, and antenna sections.

The structure of conventional products requires at least 12 components. In contrast, the structure we designed allows the functions of multiple components to be integrated into one component, resulting in a great reduction of the number of components. Thus, larger internal device mounting space is acquired.

The following explains the effects of using the heterogeneous material for the molding case, considering the primary design objectives of this portable two-way radio:

(1) Size reduction

With conventional products, the operating button section was designed as a separate component piece. This made designing a structure that fits components with each other necessary. In addition, conventional products used a packing structure around the button

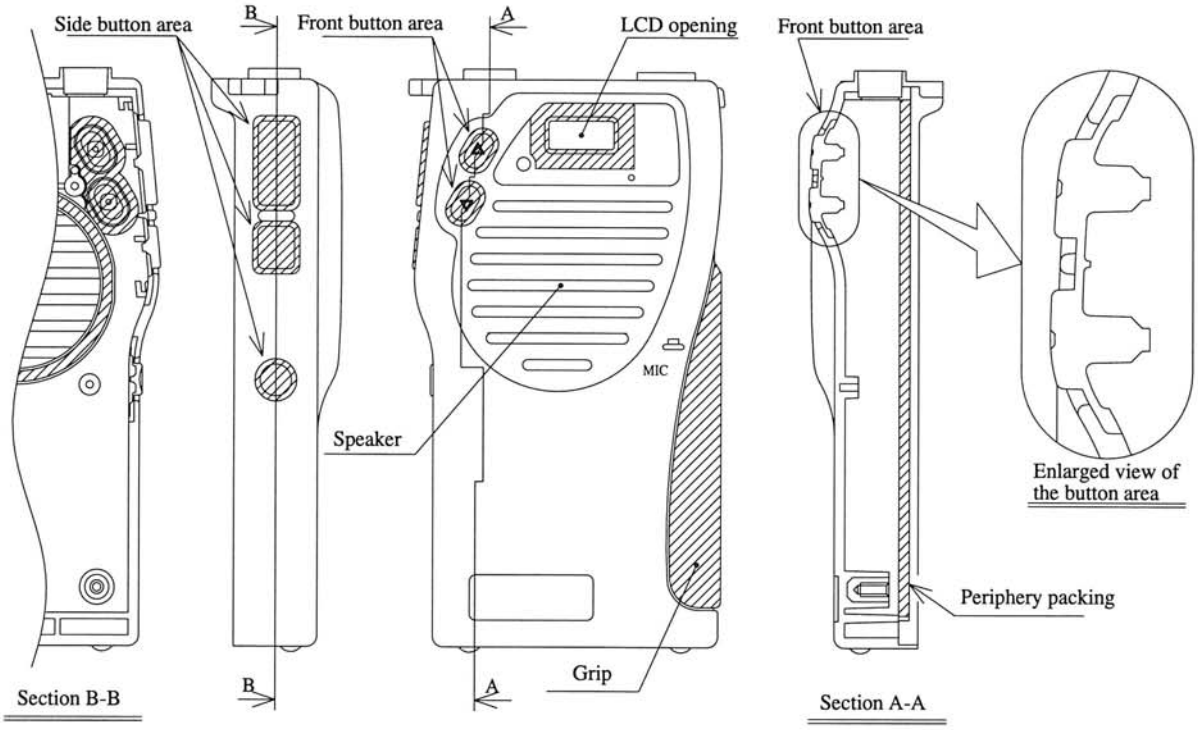


Figure 8. Heterogeneous material molding case

area to achieve a splash-proof structure. For this reason, a large number of components were used and the internal structure was complex. Obviously, a simple structure size reduction would lead to an insufficient internal space for circuit devices.

To overcome these difficulties, we used thermoplastic elastomer to mold the buttons themselves and hinge areas for vertical movement. This reduced the wall thickness of the heat-fused section to about 2 mm, including the hard resin portion. Thus, a thinner structure was made. The same method was also used for the LCD opening, and speaker and microphone sections.

With conventional products, the periphery packing area was also designed as a separate component piece. Therefore, a groove had to be provided on the case to fit the packing into the case. This hindered the size from being further reduced. We integrated the case and packing into one component and succeeded in acquiring more internal space for component mounting. In this way, further size reduction was achieved.

(2) Splash-proof structure (JIS C0920 protection class 4)

The most common method of achieving a splash-proof structure is to use packing, which is made of silicone rubber or similar material as a separate component. However, this method is problematic. Splash-proof performance varies depending on the deviations in the assembly process. In contrast, the packing of this two-way radio involves very few performance deviations because it is heat-fused with hard resin at the injection of the molding. In this way, stable splash-proof performance was achieved.

(3) Cost reduction

As mentioned above, the considerable reduction in the number of components allowed the total cost of molds and components to be reduced. It also led to the reduction of processing costs because the work required for assembly was reduced. In this way, considerable cost reduction was achieved.

3.5 Use of electronic means of adjustments

With conventional radios, modulation factor adjustment, transmission power adjustment, and other adjustment work were performed using a semi-fixed resistor placed on the internal PC board. However, acquiring enough space for portable two-way radios for this purpose was difficult. Adjusted points were often those points where adjustment work was difficult. Therefore, manufacturing workability and maintainability were very low. In addition, there were problems of aging and reliability because the adjustment device itself had moving parts.

This two-way radio uses electronic means to adjust the parameters listed in Table 6. Adjustments can be performed from a PC connected to the external speaker/microphone terminal of the portable two-way radio without opening the case of the portable two-way radio. We also developed a software program, which runs under Windows 95, that allows users to set and adjust various parameters on a PC monitor.

Table 6 Electronically controllable parameters and adjustment value setting methods

Parameter	Adjustment value setting method
Maximum transmitting modulation	Electronic variable resistor (0.5 dB/step)
Tone squelch modulation	
DCS modulation factor	
DCS balance adjustment	
MSK modulation factor	
Adjustment of transmitting and receiving frequencies	D/A converter (20 mV/step)
Adjustment of transmitting power	
Adjustment of receiver noise squelch depth	

This adjustment circuit considerably improved maintainability. Also, the need to open the case at adjustment or setting was eliminated. Therefore, preventing secondary failure, which results when the compact portable two-way radio is disassembled, is now possible.

Furthermore, stability against aging and reliability are improved because the adjustment device does not have any moving parts.

3.6 Sele-call function for simplified radio communication

The sele-call function, which allows "efficient communication" is increasingly necessary. "Efficient communication" is the function that permits users to call a specific mobile station using an alarm tone and communicate only with specific mobile stations or groups.

Previously, only voice communication was allowed for simplified radio communication. In 1991, simplified

radio stations were obligated to send ATIS (Automatic Transmitter Identification System) signals. In 1993, restrictions were relaxed, allowing additional ATIS data to be freely changed as required. Thus, the sele-call function became available also for simplified radio communication.

Figure 9 shows the ATIS signal data format for the Series-76 simplified two-way radio.

The digital squelch function, which conventional products also have, uses the same ATIS additional bits as the sele-call function. Therefore, users must select either the sele-call or digital squelch function.

This simplified two-way radio includes the following sele-call functions: individual calling, individual communication, group communication, broadcasting, call cancellation, among others. The system capacity was determined considering the number of users of simplified radio stations. The system can accommodate up to 100 stations including base stations. The number of groups can be freely assigned in the range from 1 to 15 to assure flexible response to stations added in the future.

To keep compatibility between portable and car-borne two-way radios, we also made minor changes to the design of the conventional Series-71 car-borne simplified two-way radio. The Series 71 now supports the sele-call function. The sele-call controller, which selects a mobile station specified as the target of calling or communication, can be used together with the Series-71 car-borne two-way radio. This combination allows users to easily construct a multifunction sele-call system, which involves both portable car and car-borne two-way radios.

3.7 DCS function

For simplified radio communication, assigned frequencies are shared by multiple users. Therefore, tone squelch has been used to prevent users from overhearing others. However, only 33 tone frequencies are assigned to simplified radios. This gives rise to the tone frequency duplication problem among users. Also, serious radio interference problems result, especially in large urban areas.

To address this radio interference problem, this two-way radio has a conventional tone and digital squelch (DCS) squelch function as standard features. The DCS function became available for simplified radio stations due to recent restriction relaxation.

DCS is a system that identifies users using 83 types of cyclic digital codes, each of which consists of 23 bits of NRZ data.

Figure 10 is a block diagram of the DCS encoding circuit of the Series-76 portable two-way radio.

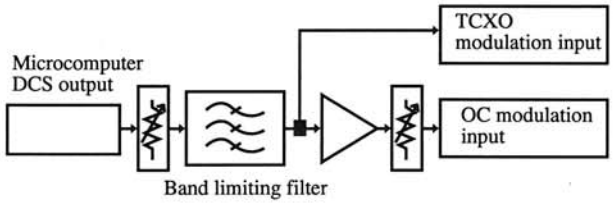


Figure 10. DCS (Digital Code Squelch system) endocding circuit

The DCS encoding circuit must modulate at least 10-Hz square waves because of its code configuration. However, the PLL synthesizer method, which is widely used in conventional two-way radios, has the following problem. When only the wave from a voltage-controlled oscillator (VCO) is modulated, the low-frequency areas will not be modulated because of the PLL loop response characteristic. In contrast, the high-frequency areas are not modulated when the save from the reference oscillator outside the PLL loop is modulated.

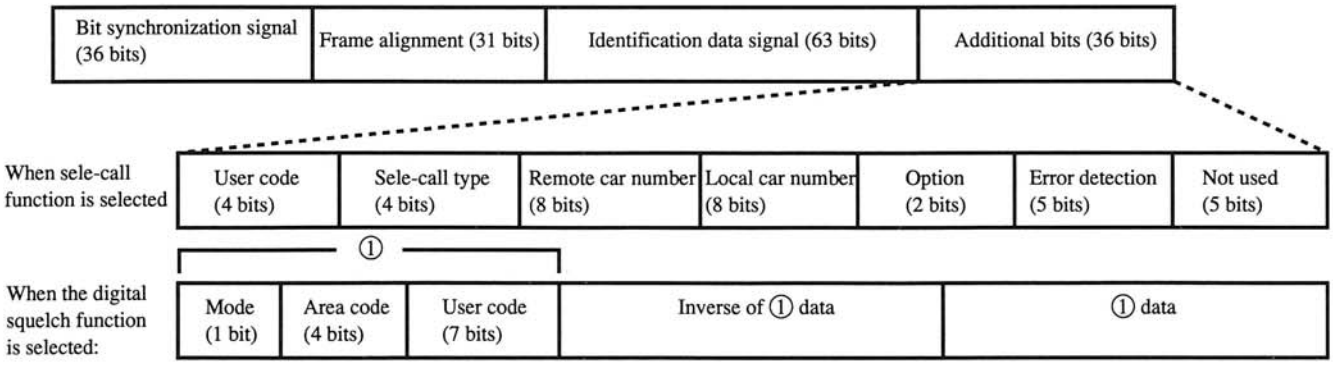


Figure 9. Format of ATIS (Automatic Transmitter Identification System) signal

To solve this problem, this two-way radio obtains the desired modulation factor and modulation waveform by modulating both the outside and inside components of the PLL loop to balance them.

The DCS decoding circuit performs band filtering to limit the discriminator output from the reception section only to DCS components. The resulting DCS components pass through the comparator circuit. Then, these components enter the microcomputer for code determination to control muting of reception voice output.

The DCS function of this two-way radio conforms to the RCR standard (specified by Association of Radio Industries and Businesses). When combined with the conventional tone squelch function, the DCS function can identify 116 users per channel. We believe that this is sufficient to remedy radio interference problems in urban areas.

4. Afterword

Typical in the development and in-house manufacturing of a multichip module, this two-way radio uses various new technologies that are not in conventional two-way radios. Full use of Fujitsu TEN's capabilities in various fields including technology development, evaluation, production, and manufacturing engineering went into the designing of this new two-way radio.

Immediately after introduced in the market, this two-way radio was adopted by various organizations, including the Japan Highway Public Corporation, leisure facilities (e.g., skiing grounds and theme parks), harbors, and transportation and security companies. It is highly reputed among users.

We hope that this two-way radio will continue to gain in popularity.

We believe that mobile telecommunication is essential in promoting intelligent transport system (ITS) business. We plan to make further efforts by taking advantage of knowledge and experience accumulated through the development of mobile telecommunication related equipment.

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