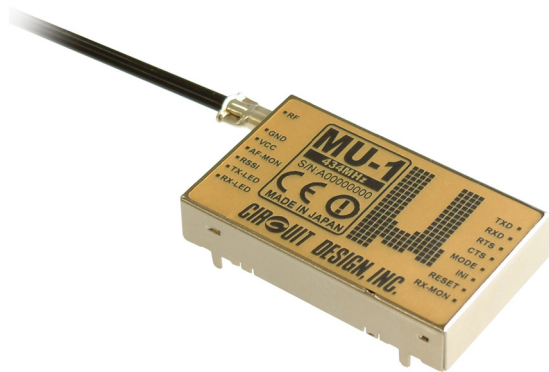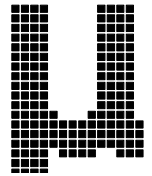# Embedded low power radio modem

MU-1 434MHz

Implementation Guide

Version 1.0 (Apr. 2006)

The MU-1-R is an RoHS compliant radio modem. "-R" is added as an identification to RoHS compliant products.
In this Operation Guide, please read "MU-1" as "MU-1-R"

CIRCUIT DESIGN, INC.,

7557-1 Hotaka, Azumino
Nagano 399-8303, JAPAN
Tel: +81+(0)263-82-1024
Fax: +81+(0)263-82-1016

E-mail: info@circuitdesign.jp
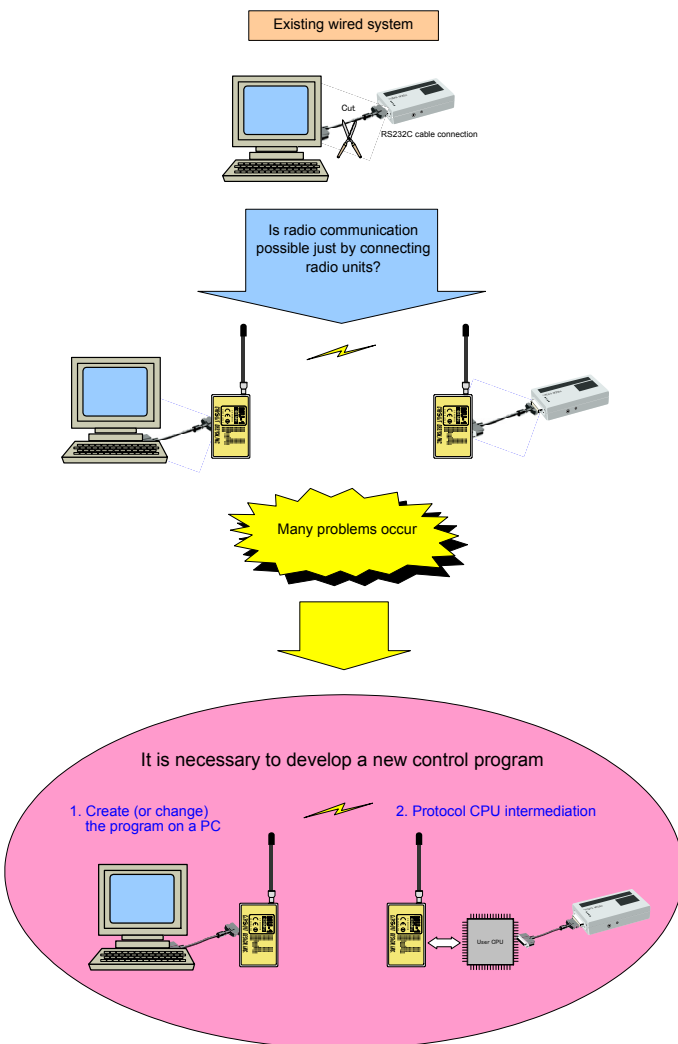Web site: http://www.cdt21.com

Contents

* This document consists of information for users who are considering implementation of the MU-1. Please refer to the Operation Guide of the product for details.

CIRCUIT DESIGN, INC.

Changing to a Radio System

■ Replacing an existing wired system with radio

Is it possible to replace an existing wired system with radio throughout, simply by replacing the cables with radio units (MU-1)? Although many users hope that this is the case, unfortunately it is not that simple. It is necessary to develop new programs for the CPU and PC that control the MU-1 and the user system.

Existing wired system

Cut

RS232C cable connection

Is radio communication possible just by connecting radio units?

Many problems occur

It is necessary to develop a new control program

1. Create (or change) the program on a PC

2. Protocol CPU intermediation

User CPU

The reasons are;

1. A single signal path

With a wired system, full duplex communication is established, but with radio communication, data cannot be sent between the transmitter and the receiver at the same time as there is only one signal path. In addition, since it takes a while to switch between transmitting and receiving, real time communication is not possible. This is called half duplex communication (simplex working). Since the control program for the wired connection itself is based on full duplex communication, it is necessary to develop a new program for half duplex communication.

2. It is necessary to send the status of all the control lines

A number of control lines are used for normal wired systems. For this reason communication cannot be established with radio unless the status of all the control lines is sent. (If the expected signal does not arrive, the existing program will stop.)

3. Communication by packet unit

Radio communication uses packets. With wired connections, the communication protocols vary with the equipment. It is necessary to change these for communication using the packet units of radio equipment.

4. Identification codes are necessary

With wired systems, the other party in communication is determined by the connection of the communication line. However with radio, any number of radio units can receive the transmission, so it is necessary to add an identification code to the data in order to specify the other party.

5. Communication errors occur (packets do not reach the receiver)

Data communication errors in cables occur only very rarely with wired systems, but with radio communication, packet errors occur even over short distances. For this reason, it is necessary to use a control program that assumes that some packets will not reach the receiver.

■ The causes of transmission errors

With radio communication, data packet errors occur due to a variety of error factors. How the system behaves when data does not arrive at the receiver is an important point of system design.

Obstacle

Naturally occurring noise - Solar, atmospheric, lightening, rain

Cable loss
Connector loss

Multipath fading

Source station

Target station

Emission power
Wt [W]

Receiving power
Wr [W]

Electrical circuit noise
Design defects

Differences due to ground reflection, absorption, ground humidity and soil type.

Noise from other radio equipment, industrial equipment, consumer equipment, and vehicles

Noise and loss that cause errors

Basic Functions

■ Communication method

Besides 1-to-1 transmission and transmission between several stations in the same group (1:N), the MU-1 also allows transmission via relay stations. In addition, it can transmit a maximum of 255 bytes of data at one time.

[The basics of communication]

When you issue a data transmit command from the source station PC or microcomputer (CPU) to the MU-1, a data transmission response is returned from the source station MU-1 that indicates that a data transmit command was received. The target station MU-1 outputs a receive response that includes the transmission data from the source station.
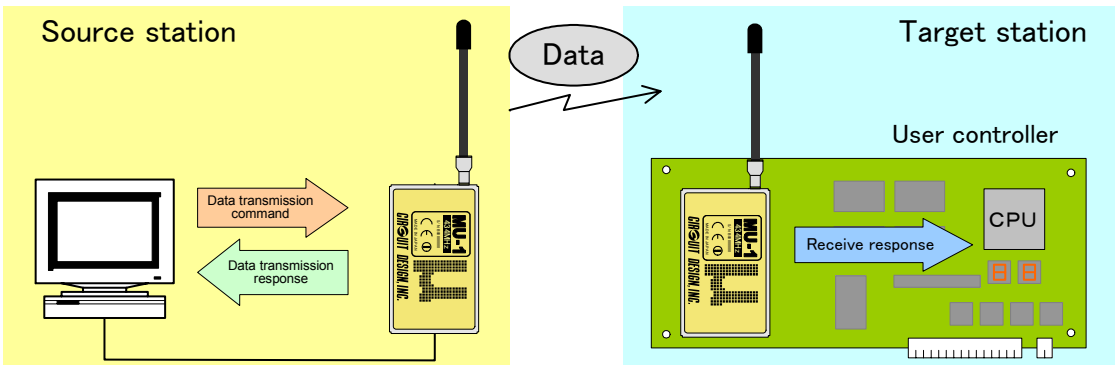
[Relays]

You can create a relay with a maximum of 10 MU-1 stations. If you transmit data from the source station specifying the route information, the data is transmitted to the target station via the relay stations specified.

In addition, if you select the receive acknowledgement (ACK) command option, the target station returns a data receive acknowledgement (ACK) after receiving the data.
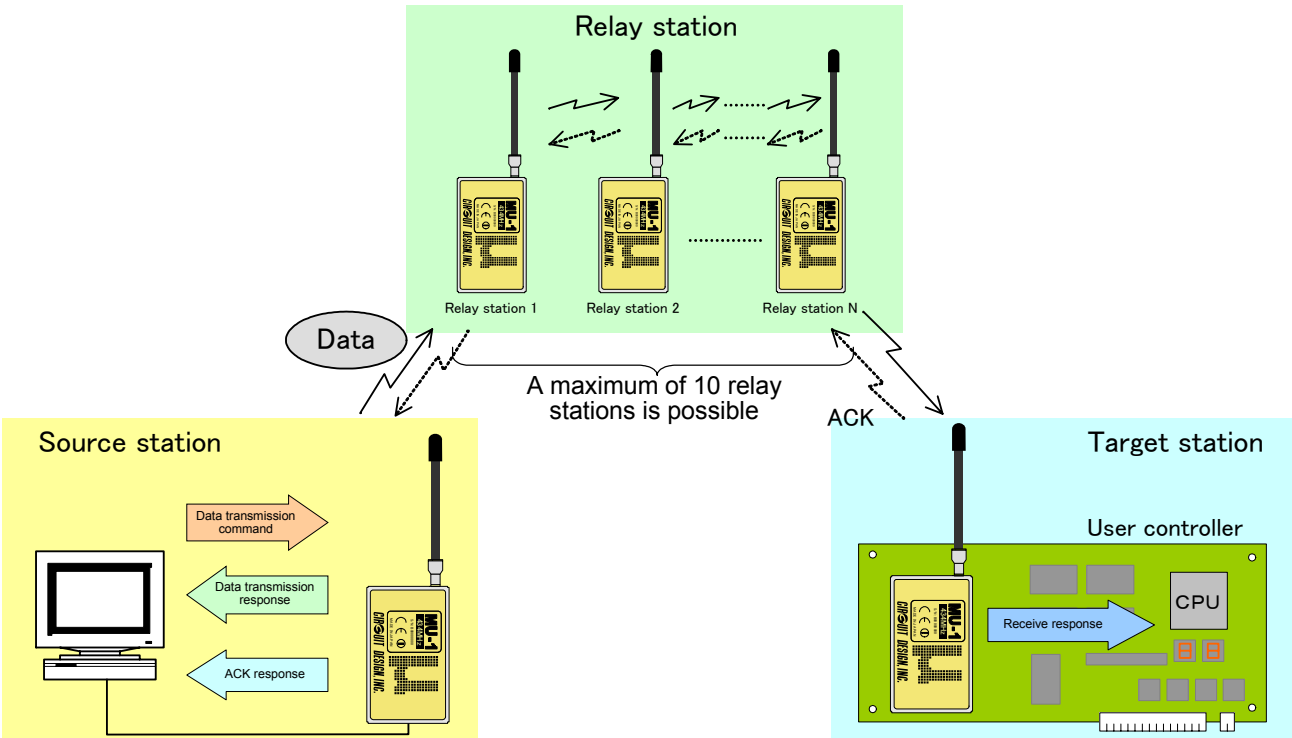
■ System configuration

1. Same area system

When you are not using relay stations, enter the target station Equipment ID as the Destination ID, and then issue the data transmit command.
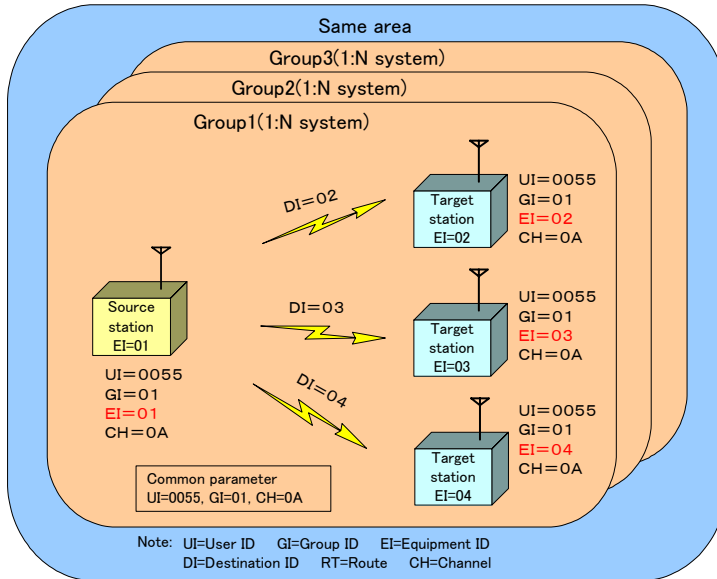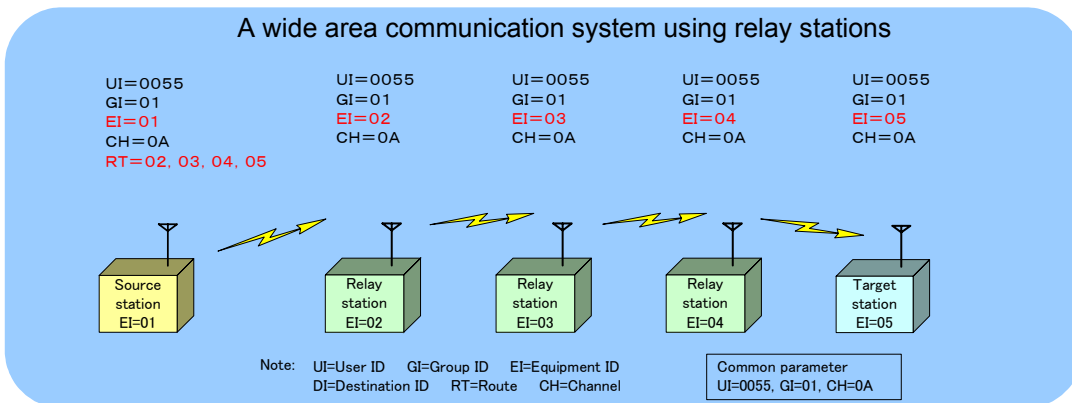

Same area

Group3(1:N system)
Group2(1:N system)
Group1(1:N system)

DI=02
Target station EI=02
UI=0055 GI=01 EI=02 CH=0A

Source station EI=01
UI=0055 GI=01 EI=01 CH=0A

DI=03
Target station EI=03
UI=0055 GI=01 EI=03 CH=0A

DI=04
Target station EI=04
UI=0055 GI=01 EI=04 CH=0A

Common parameter UI=0055, GI=01, CH=0A

Note: UI=User ID   GI=Group ID   EI=Equipment ID
DI=Destination ID   RT=Route   CH=Channel

2. Wide area system

When you are using relay stations in a wide area system, enter the route information in the route register, and then issue the data transmit command.
* Alternatively, you can also enter the route information directly in the data transmit command.

A wide area communication system using relay stations

UI=0055 GI=01 EI=01 CH=0A RT=02, 03, 04, 05

UI=0055 GI=01 EI=02 CH=0A

UI=0055 GI=01 EI=03 CH=0A

UI=0055 GI=01 EI=04 CH=0A

UI=0055 GI=01 EI=05 CH=0A

Source station EI=01

Relay station EI=02

Relay station EI=03

Relay station EI=04

Target station EI=05

Note: UI=User ID   GI=Group ID   EI=Equipment ID
DI=Destination ID   RT=Route   CH=Channel

Common parameter UI=0055, GI=01, CH=0A

■ The role of the relay function

1. Increasing the communication area

You can increase the communication area by using a maximum of 10 MU-1 relay stations.
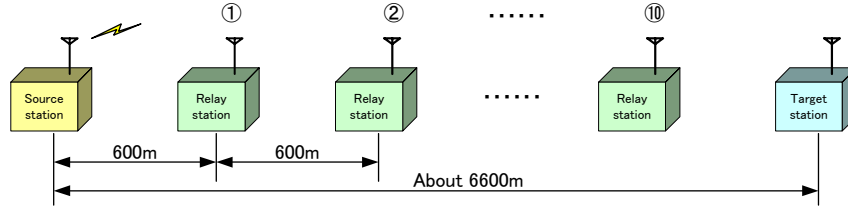
2. Establishing stable communication

The purpose of the relay function is not only to extend the communication range. It can also ensure stable communication when the system is located in a place where the status of radio waves is poor, such as an automated factory line, indoors, or urban areas, even where distances are short.
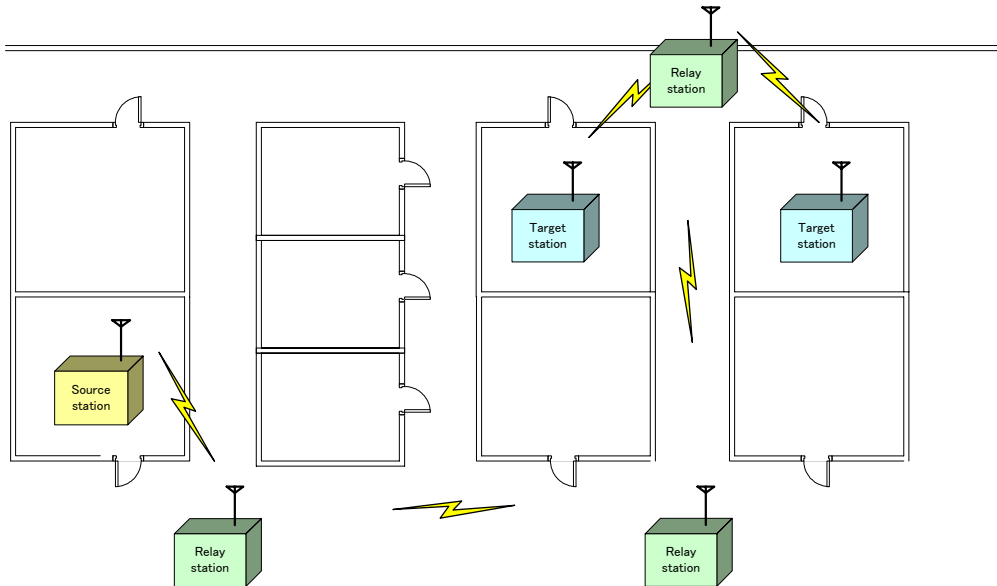

3. Flexible transmission paths

If you place relay stations in several locations, even if communication with one relay station becomes impossible, you can still send the data to the target station by a different route. In this case it is first necessary to set the route before issuing the data transmission command.
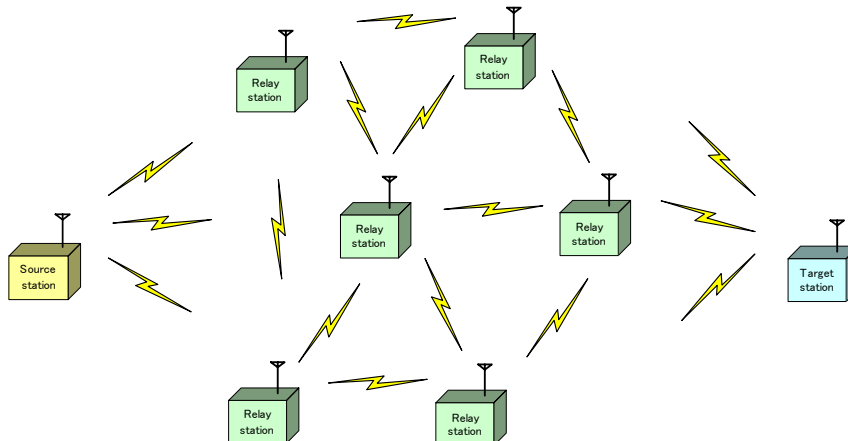
Main Specifications

■ Internal configuration

The most significant feature of the MU-1 is that it uses the UART interface used by many CPUs, and it comes with a built-in command interpreter. Conventional radio units require users to handle troublesome processes such as radio link processing, communication protocol processing, base band processing and the like, but these processes are all handled internally by the MU-1, and the radio component can be controlled easily with simple commands.

In addition, thanks to the UART interface, it is now a simple matter to connect the MU-1 directly to a single-chip CPU, or to connect it to the COM port (RS-232C) of a PC.

As a result, compared with conventional radio units, the burden of software and hardware development is significantly reduced, and this also shortens the system development period.

Diagram
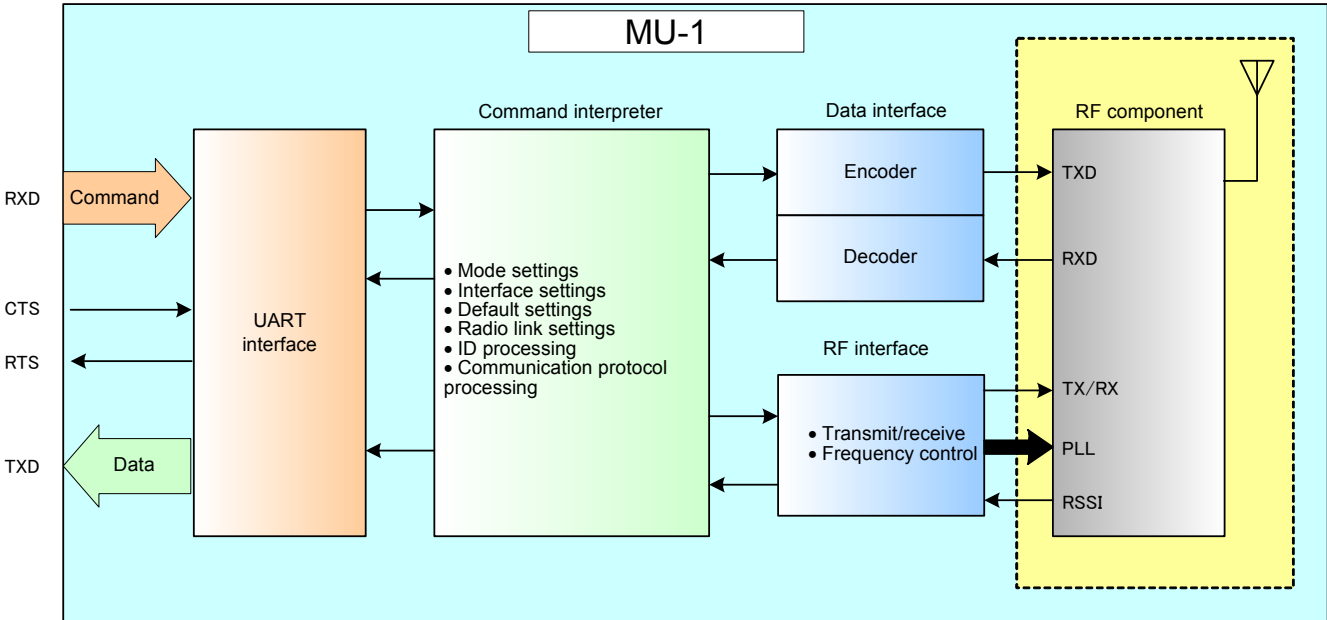
■ Commands

The MU-1 uses the following 5 types of command. Using these commands makes it an easy matter to transmit data, check the radio status and perform other operations.

Command	Main function
Data transmitting command	Transmit data
Control command	MU-1 basic operation settings
Test command	Checking radio status and various tests
Extended command	Various extension functions

■ Channels

The frequency bands that can be used with short range devices (SRD) are regulated officially. According to these regulations, the MU-1-434 is channelised in 25 KHz steps and has 64 channels in the ISM 434 MHz band (433.050 MHz to 434.790 MHz).

Channel span
25.0kHz

| 0ch | 3ch | 4ch | ...... | 19ch | 63ch |
| 433.200MHz | | | | | 434.775MHz |
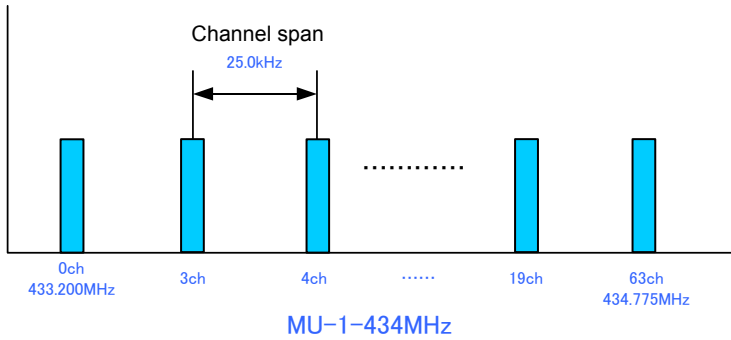
MU-1-434MHz

■ Field intensity

For the MU-1 to receive radio waves from the source station reliably, a signal level of about -87 dBm at MU-1-434 MHz is necessary.

MU-1-434MHz

Stable

−80dBm

Receive level

−90dBm   -87 dBm: Level at which stable communication is possible

−100dBm

−110dBm   -108 dBm: Level with a packet error rate of 0.1%

Unstable

Noise floor   Reduce system noise floor level to below -127 dBm

Stability of Communication

■ Modes

Command mode

Normally the command mode is used
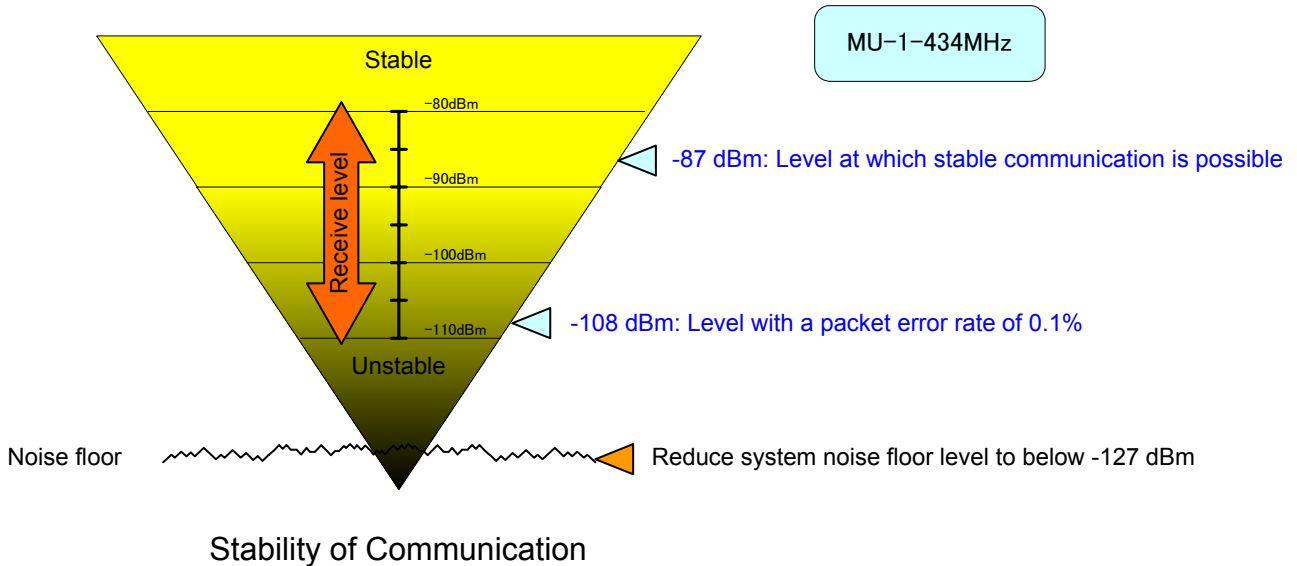
Binary mode   Text mode
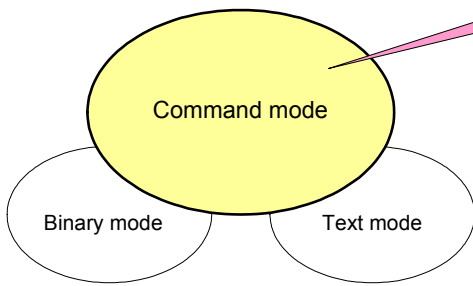
= Uses of the command mode =
1. UART parameter settings (bit rate, data size, parity bit, and stop bit)
2. Operation mode setting (command mode, binary mode, and text mode)
3. Channel settings
4. Link ID settings (User ID, Group ID, Equipment ID, and route information)
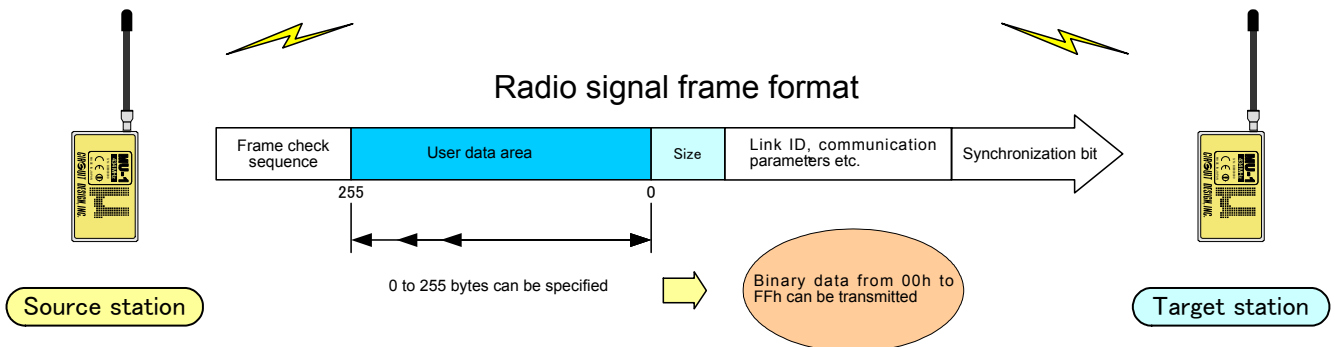5. Issuing data transmit commands
6. Issuing monitor commands (acquire RSSI information command and change system channel command)
7. Other operations

The MU-1 has 3 modes, the command mode, binary mode, and text mode, but applications are usually created using the command mode. In the command mode, radio waves are emitted towards the target station simply by attaching the user data to a data transmit command and sending it to the MU-1.

* Since the binary mode and text mode are modes for testing, there are certain restrictions on communication when using them.

■ User data size

Any user data size from 0 bytes to a maximum of 255 bytes can be specified. Since it is processed as a data size, binary data from 00h to FFh can be transmitted.

Radio signal frame format

| Frame check sequence | User data area | Size | Link ID, communication parameters etc. | Synchronization bit |

255   0

0 to 255 bytes can be specified

Binary data from 00h to FFh can be transmitted

Source station   Target station

■ Effective radio communication speed

The radio communication speed of the MU-1 is a fixed value of 9,600 bps, but since there is an overhead in the communication protocol, its effective radio communication speed (actual bit rate) is about 6,800 bps.

Compared with the data rate of a serial interface, the bit rate of radio is slower, so hardware flow control is necessary, and real time transmission is not possible. It is necessary to identify whether this matches your system requirements.

Radio communication speed	
Bit rate	Effective bit rate
9600bps	6800bps
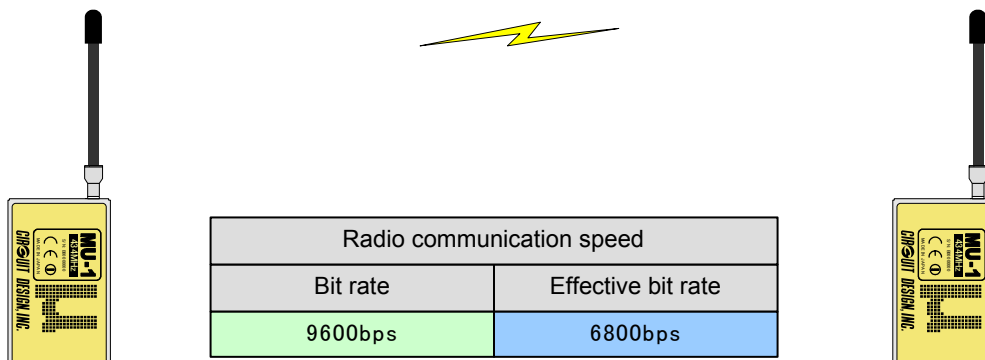
■ Time to establish link

This is an example of when, in order for the system to establish a link, n bytes of data are sent from the source station, and m bytes of data are returned from the target station. In practice, it is also necessary to take into consideration the time required for user system control at the target station.

Example:

Diagram when n bytes of data are transmitted from the source station, and m bytes are transmitted from the target station
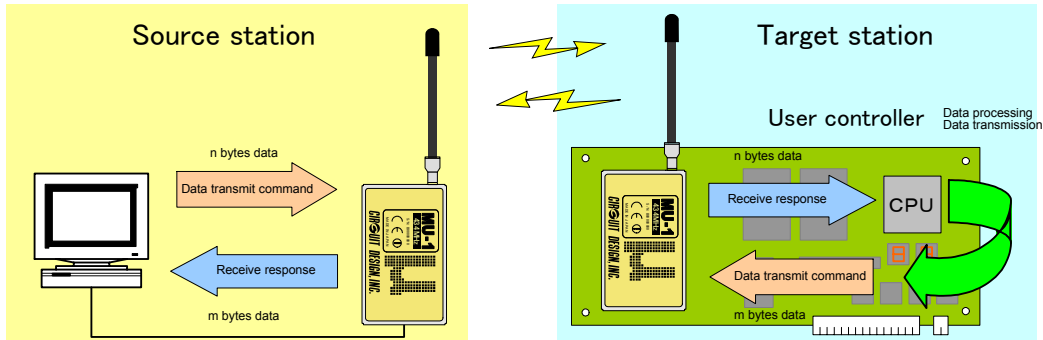
Time to establish link (when the relay function is not used, and 1 frame is transmitted and received)
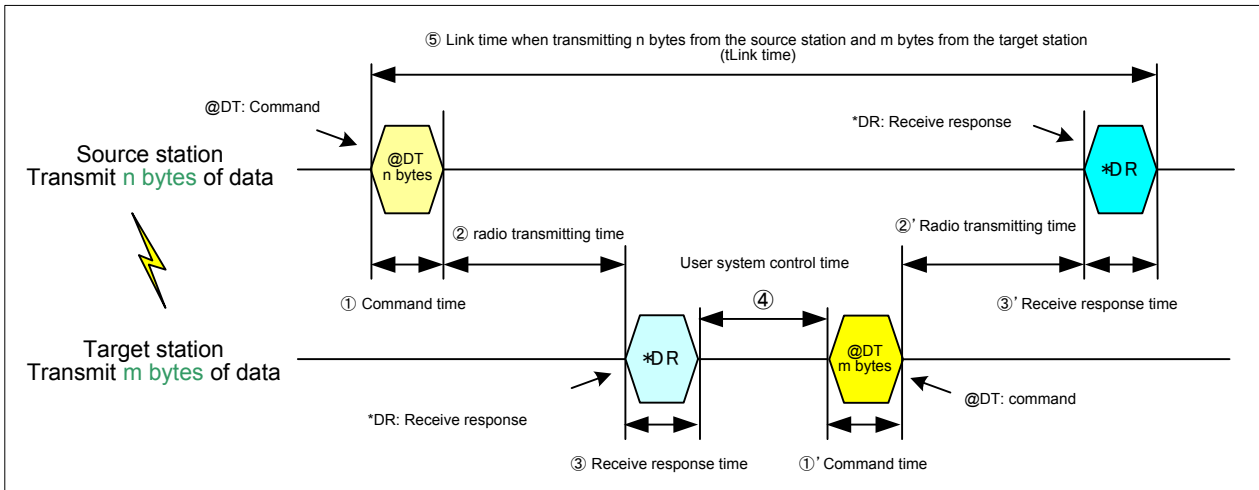
| | Command time | Radio transmitting time | Receive response time | ① + ② + ③ |
	① (①')	② (②')	③ (③')	①' + ②' +③'
n (m) = 10	9 ms	44 ms	9 ms	62 ms
n (m) = 20	14 ms	55 ms	15 ms	84 ms
n (m) = 50	30 ms	86 ms	30 ms	146 ms
n (m) = 100	56 ms	138 ms	56 ms	250 ms
n (m) = 200	108 ms	242 ms	108 ms	458 ms
n (m) = 255	136 ms	299 ms	137 ms	572 ms

⑤ tLink time (when ④ = 0 ms)

n = 20 bytes, m = 10 bytes	n = 100 bytes, m = 20 bytes	n = 255 bytes, m = 100 bytes
146 ms	333 ms	822 ms

Operating conditions:

1. n bytes of data are sent from the source station, and after the target station performs received signal processing, m bytes of data are returned to the source station.
2. The speed of the UART interface is 19,200 bps for both stations.
3. The user system control time is not included.

■ Radio link

In order to avoid radio interference with other stations and to achieve highly reliable communication, the MU-1 uses the Link ID concept. If the Link ID of the transmitting end and receiving end do not match, communication is not established. When you are using relay stations, set the data transmission path as route information in the route register. When you are not using relay stations, specify the target station Equipment ID as the Destination ID of the source station.
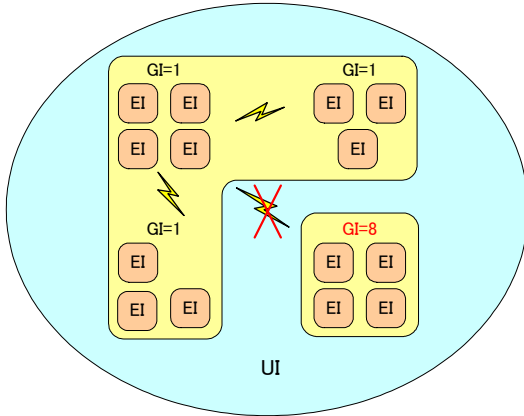
Item name		Size	Value	Content
UI	User ID	2bytes	0000–FFFE	Set a password
GI	Group ID	1byte	00～FF	No. 0 to 255
EI	Equipment ID	1byte	01～FE	No. 1 to 254

* Group ID and Equipment ID can be set freely within the range above

* All equipment in the system has the same frequency channel.
* Communication is not possible between different Group IDs.

1. Link ID

*UI (User ID): This identifies the user of the system, and the default value is 0000.
*GI (Group ID): This defines groups for areas and applications within the range of the same User ID.
*EI (Equipment ID): This identifies the equipment, and all equipment within the same group has a different ID.

2. Conditions for establishing a link

The conditions for establishing a link are as follows.

(1) The frequency channels must be the same
(2) The User ID must be the same
(3) The Group ID must be the same
(4) The destination ID specified in the source station must match the Equipment ID of the target station
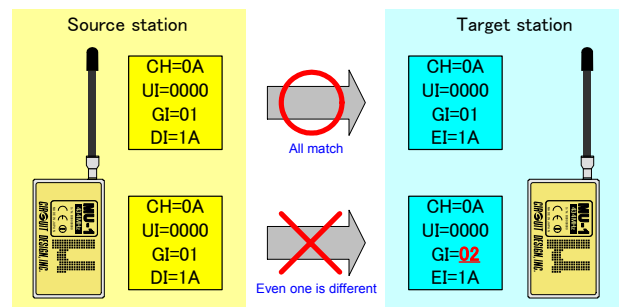
* Normally, Group IDs are assigned to each area and application, but it is possible to change the Group ID with each communication in order to communicate outside the Group ID.
* The Link ID and the content of the route information can be fixed (saved) in the EEPROM, so that the information is saved even when the power is turned off.

3. Route information

When you are using relay stations, set the information of the route from the source station to the target station in the route register, and then issue the data transmit command. The register consists specifically of the Equipment IDs of the relay stations used, and the Equipment ID of the target station.
* Route register: This sets and saves the route information for sending data to the target station.
* Route information can also be entered directly in the data transmit command.

Commands and Responses, and Receive Responses

When a command is issued to the MU-1, a response is always returned from the MU-1. When developing a program, a process corresponding to each response must be performed. When a data transmit command is issued, besides the data transmission response, a receive response is output by the target station.
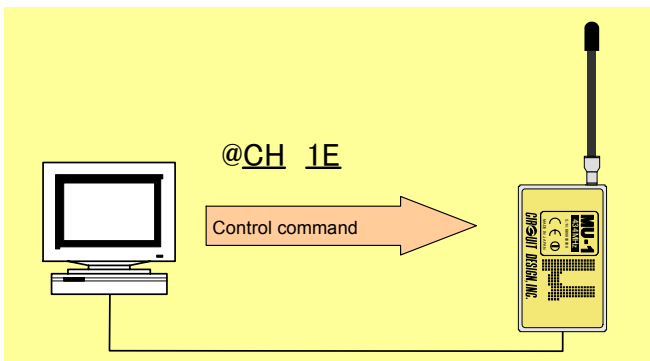
Source station		Target station
Command	**Main response**	**Response**
Control command	Control response	
Data transmit command	Data transmission response	Receive response
	(ACK response)	
Test command	Test response	
	(Receive response)	
Extended command	Extended response	
	(Receive response)	
(All commands)	Error response	* An error notification in response to the command format.

■ **Control commands and control responses**

Types of control commands

Control commands are used for UART parameter settings, channel settings, mode settings, Link ID settings and so on. When a response is required, the corresponding processing is necessary.

Example: Changing channels   Setting the channel to 1E (30) ch.

① Issue the control command

@CH 1E

Control command

Channel setting command
'C' = 43h, 'H' = 48h

Terminator
'C_R': Recovery code = 0Dh
'L_F': Line feed code = 0Ah

@ CH 1E C_R L_F

Prefix
'@' = 40h

Channel number
shows the channel
Specified with 2-digit Hex value
When 30 ch = '1E'
'1' = 31h, 'E' = 45h
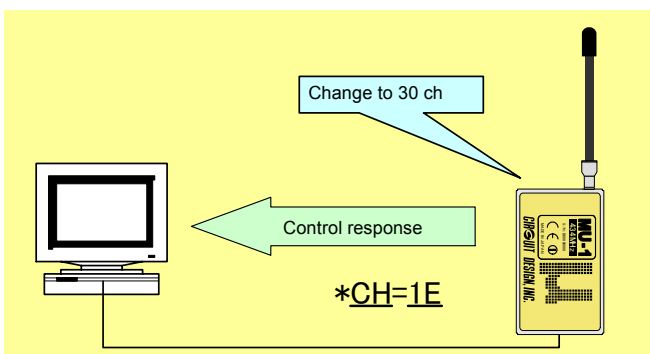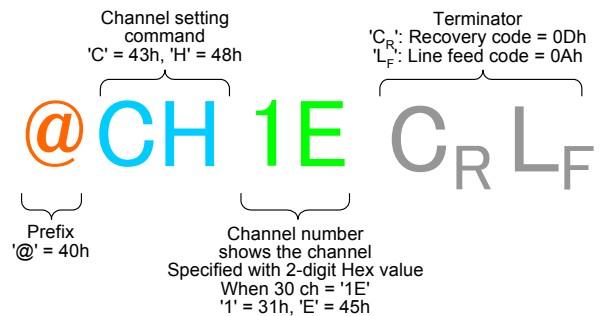
②Return frequency change control response

The frequency channel changes to 1E (30) ch, and a control response is returned from the MU-1.

Change to 30 ch

Control response

*CH=1E

Channel setting response
'C' = 43h, 'H' = 48h, '=' = 3D

Terminator
'C_R': Recovery code = 0Dh
'L_F': Line feed code = 0Ah

* CH=1E C_R L_F

Prefix
'*' = 2Ah

Channel number
shows the channel 2-digit Hex value
When 30 ch = '1E'
'1' = 31h, 'E' = 45h
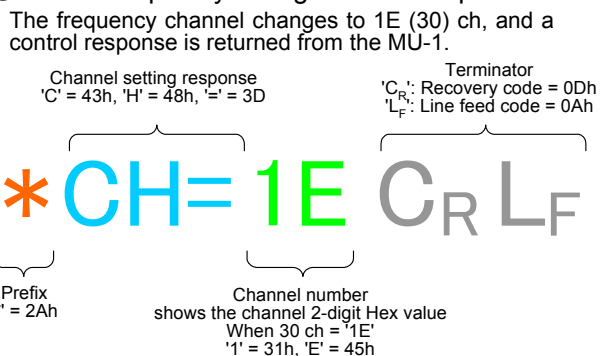
Data transmit commands, data transmission responses, and receive responses

When the data transmit command is issued in the command mode, the user data is sent to the target station. A data transmission response is returned from the source station, while a receive response is output from the target station. The receive response includes the user data.

Example: Transmitting data

Transmitting the 5-byte data "ABCDE" to the target station specified with the Destination ID.

① Issue the data transmit command

Communication command
'D' = 44h, 'T' = 54h

Transmission data
00h to FFh binary data
'A' = 41h, 'B' = 42h, 'C' = 43h, 'D' = 44h, 'E' = 45h

@ DT 05 ABCDE C_R L_F

Prefix
'@' = 40h

Data size
00h to FFh Hex value
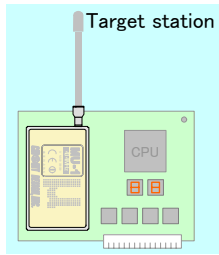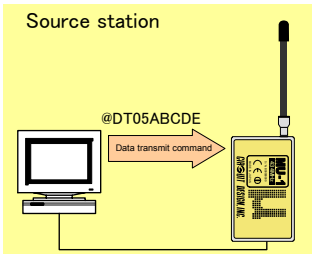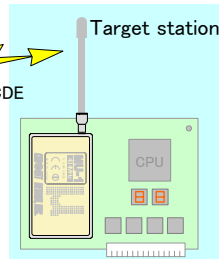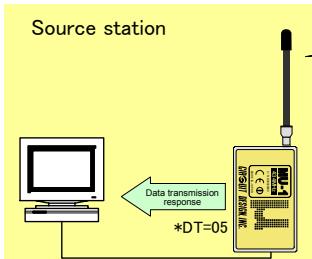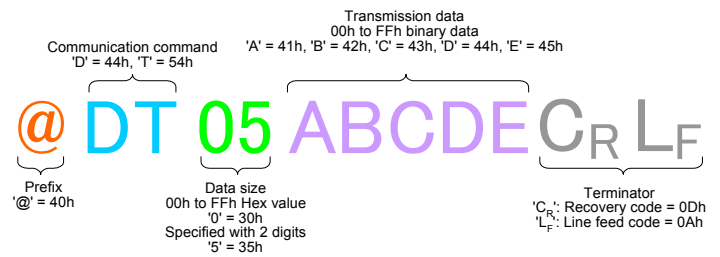'0' = 30h
Specified with 2 digits
'5' = 35h

Terminator
'C_R': Recovery code = 0Dh
'L_F': Line feed code = 0Ah

② Return data transmission response

If the data transmit command is received normally, a data transmission response is returned, and the data is transmitted to the target station.

Communication response
'D' = 44h, 'T' = 54h, '=' = 3D

Terminator
'C_R': Recovery code = 0Dh
'L_F': Line feed code = 0Ah

* DT= 05 C_R L_F

Prefix
'*' = 2Ah

Data size
2-digit Hex value from 00h to FFh
'0' = 30h, '5' = 35h
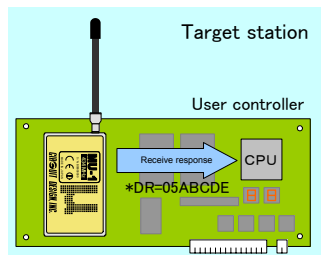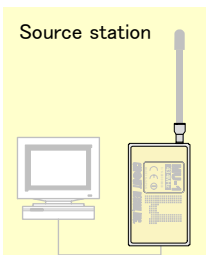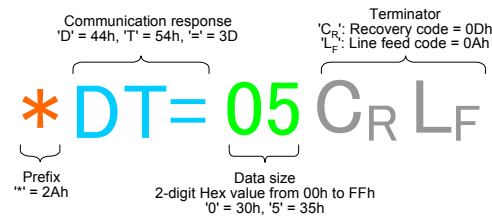
③ Output data receive

If there is no error in the data from the source station, a receive response is output from the target station. If a packet error occurs, nothing is output. Convert the data size into a numerical value, and process only that amount of data.

Receive data
'D' = 44h, 'R' = 52h, '=' = 3D

Transmission data
00h to FFh binary data
'A' = 41h, 'B' = 42h, 'C' = 43h, 'D' = 44h, 'E' = 45h

* DR= 05 ABCDE C_R L_F

Prefix
'*' = 2Ah

Data size
2-digit 00h to FFh Hex value
'0' = 30h, '5' = 35h

Terminator
'C_R': Recovery code = 0Dh
'L_F': Line feed code = 0Ah
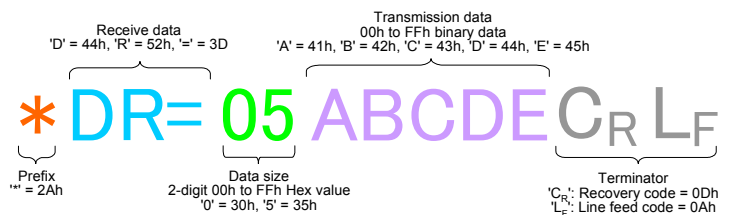
Convenient Functions

■ **RSSI (received signal level) acquisition**

1. Acquiring the source station RSSI

It is possible to check the field noise in the vicinity of the source station and the level of the signal that arrives from the target station. To measure the signal level, issue a command to make the target station issue continuous test data.

Source station field noise measurement
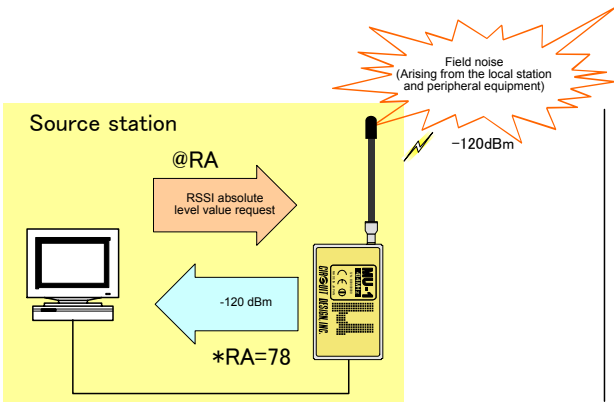
Measurement of the level of the signal arriving from the target station
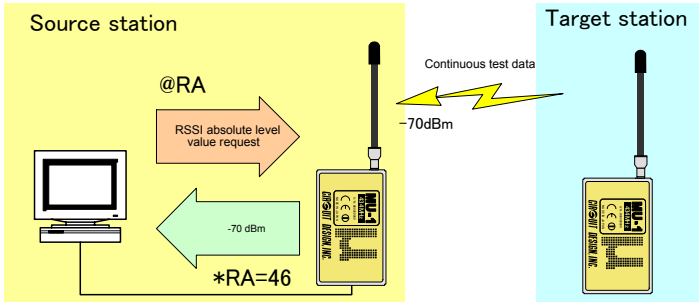
2. Acquiring the target station RSSI

It is possible to check the status of a target station located in a high or difficult to access place from the local source station.

When designing a system, you can optimize the hardware and software by checking the status of the embedded equipment (board).
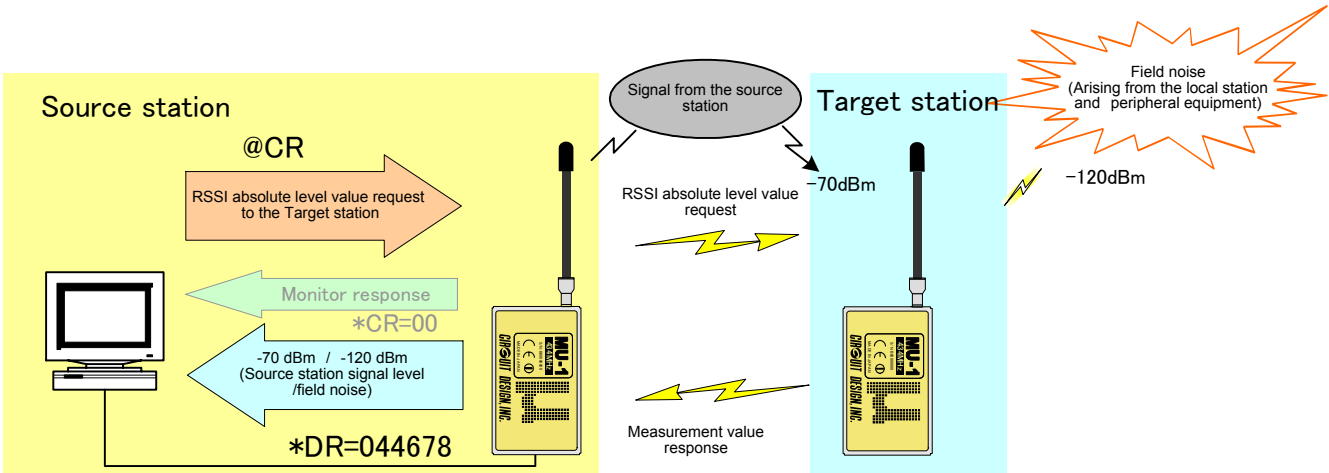
* By issuing this command using the Evaluation Program or HyperTerminal, you can display the RSSI level of the target station as an absolute value.

■ Packet test

Using the packet test command, it is possible to loop back data in the transmission path actually used for communication, and to calculate the success rate of the data.

By carrying out this test several times, it is possible to calculate the success rate of the data, enabling you to assess the reliability of the channel when you are considering implementing a system.
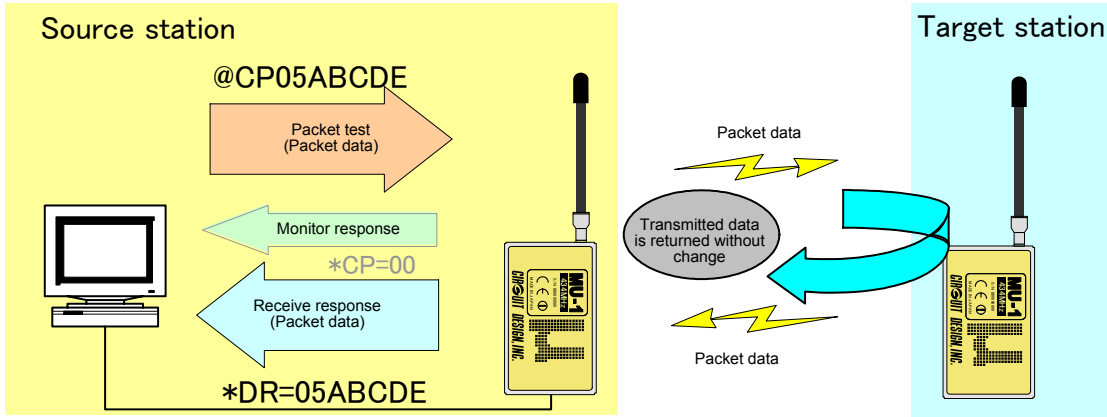
■ Changing channels

Changing all channels in the system at once

With a command from the source station, it is possible to change all the channels in the system easily including those of the relay stations.

The channel of all stations is changed at once to 2E
Command issued: @DT05@CH2E/F02,03,04,0A
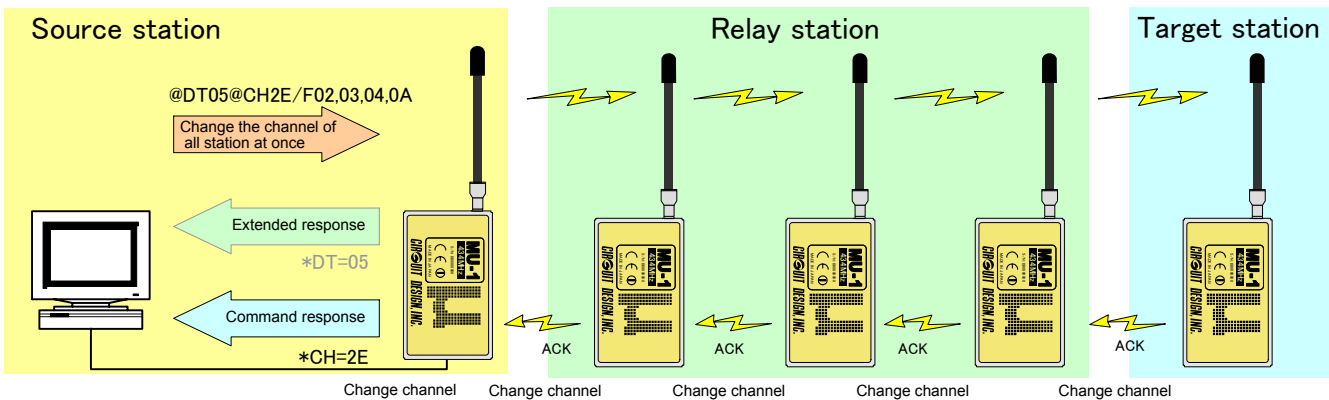
Equipment ID	EI=01	EI=02	EI=03	EI=04	EI=0A
Before change	CH=07	CH=07	CH=07	CH=07	CH=07
After change	CH=2E	CH=2E	CH=2E	CH=2E	CH=2E

* Transmit a channel changing request to the target station, and each station changes its channel and returns an ACK signal.

* When a station does not receive an ACK signal due to an error, the station does not change its own channel. In this case, it is necessary to change the channel of the station individually.

Control Procedure (Example of one-way continuous communication)

The flow chart below shows the basic form of one-way communication system control using a relay station. By setting the basic parameters such as the Link ID and so on for all the radio stations in the internal EEPROM of the MU-1, it is possible to start communication immediately with those settings the next time that you turn on the power. However, depending on the situation, it may be necessary to change the channel.

With one-way communication, there is a method that involves repeatedly transmitting the same data. The data transmit command in this example uses a transmission format based on route information set in the route register.

* With two-way communication, by using data transmit commands with an ACK response that indicates that the data was received normally, it is possible to establish more reliable communication.

■ **Default settings**

Source station
UI = 0055
GI = 01
EI = 01
CH = 0A

Relay station
UI = 0055
GI = 01
EI = 02
CH = 0A

Target station
UI = 0055
GI = 01
EI = 03
CH = 0A

Data='ABC'
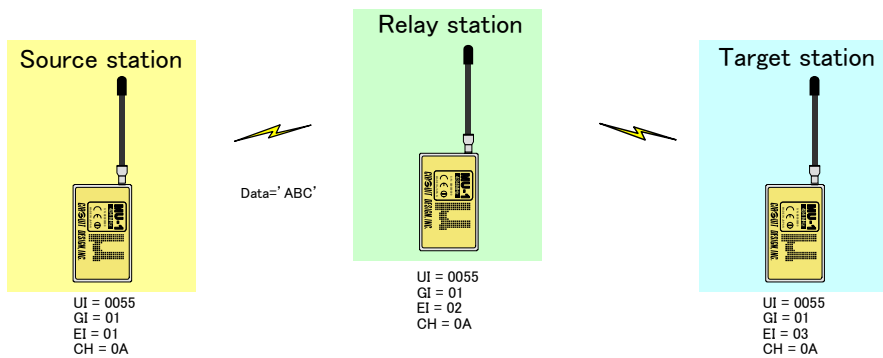
Processing common to the source station, relay station, and target station (first time only)

Power on

UART parameter settings

User ID setting
@UI0055,xxxx/W

Group ID setting
@GI01/W

Channel setting
@GH0A/W

Source station
Equipment ID setting
@EI01/W

Relay station
Equipment ID setting
@EI02/W

Target station
Equipment ID setting
@EI03/W

Source station
Route register setting
@RT02,03/W

Finish

'/W': Command option for saving the value in the EEPROM
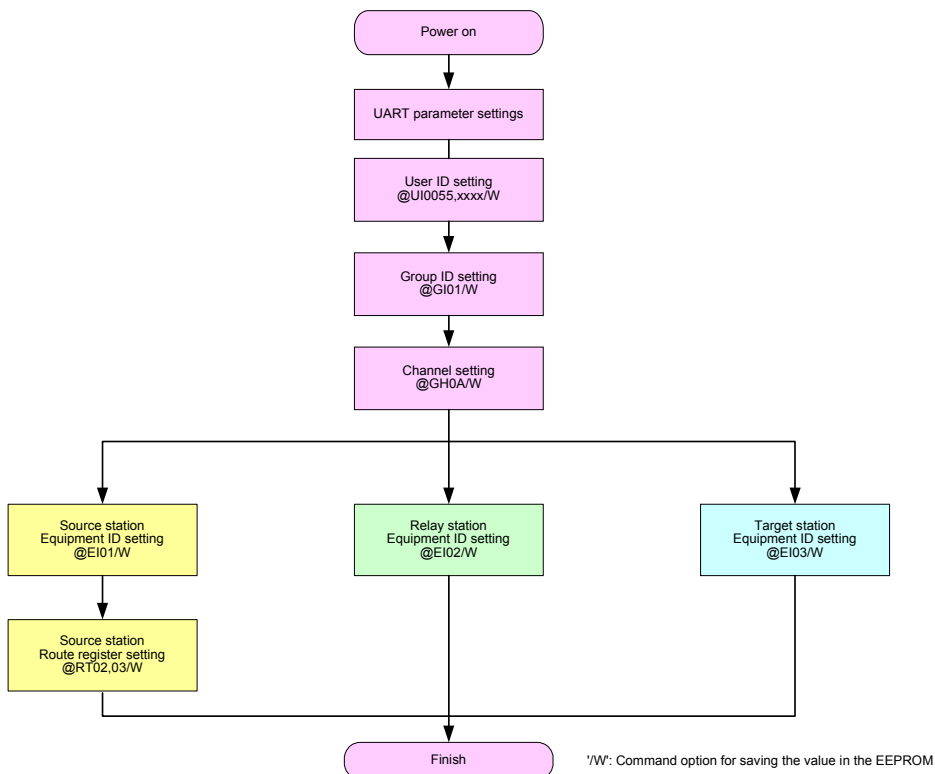
■ Control during normal operation

Source station processing

Target station processing

Power on

| Acquire data |

| Create the data transmit command '@DT03ABC/RC$_R$L$_F$' | * Note 1 |

| Issue the data transmit command UART ← Transmit command |

| Finish |

| Power on |

| UART interrupt |

| Write to the receive buffer |

| Finish UART interrupt |

| Read the receive buffer |

Process receive response '*DR='? — No

Yes

| size[0]= '0' |

| size[1]= '3' |

| Conversion of size data to a value Size = get_size(size[0],size[1]) |

| DataBuffer ↑ Acquire amount of data corresponding to the size |

| Processing in accordance with the data |

* Note 1: The format of this example data transmit command is the format used for transmission based on the route information set in the route register.

'C$_R$L$_F$': Terminator (0Dh, 0Ah)
'size[]': Text buffer
'Size': Integer
'get_size()': Function converted from text to an integer value

Flowchart of basic transmission
(with 1:1 one-way relay communication)

CIRCUIT DESIGN, INC.

Various Development Kits

■ Support for the different interfaces

There are 4 types of development kit for the MU-1; for RS-232C (MU1-RIK), for USB (MU1-UIK), for LAN (MU1-LIK), and for control of the MU-1 using a PIC microcomputer program (MU1-ADK).

In addition, a dedicated Evaluation Program is included with these kits, making it easy to make various settings and carry out communication testing.

Various development kits

RS-232C Interface kit (MU1-RIK)

USB Interface kit (MU1-UIK)

LAN Interface kit (MU1-LIK)

Application design kit (MU1-ADK)

Evaluation Program included in the kits
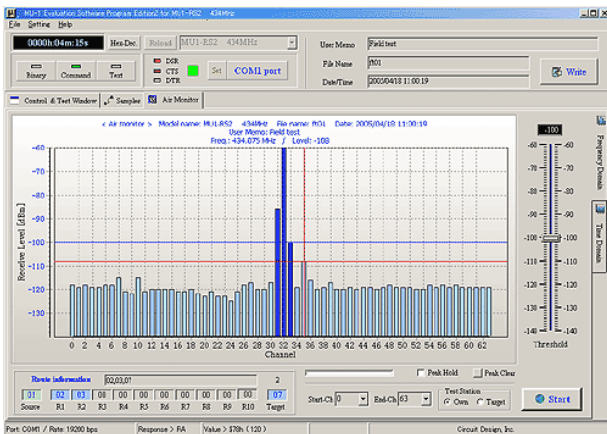
Air monitor window
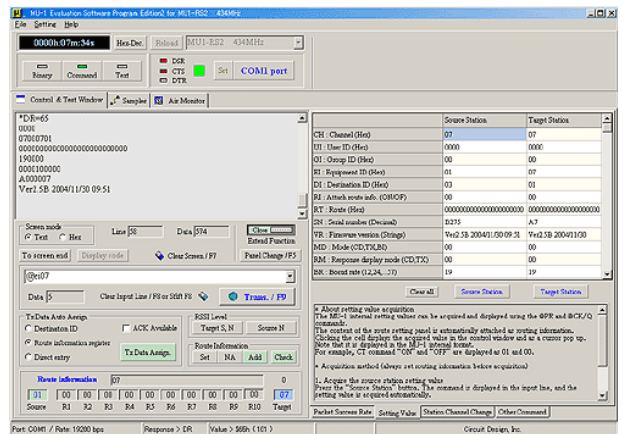
Control & Test window

Interface Method

■ Connecting to a single-chip microcomputer (direct connection)

The MU-1 can be connected with a single-chip microcomputer directly via a 1 kΩ resistor.

In order to eliminate high frequency noise in the external signal line, include a 270 nH inductor.
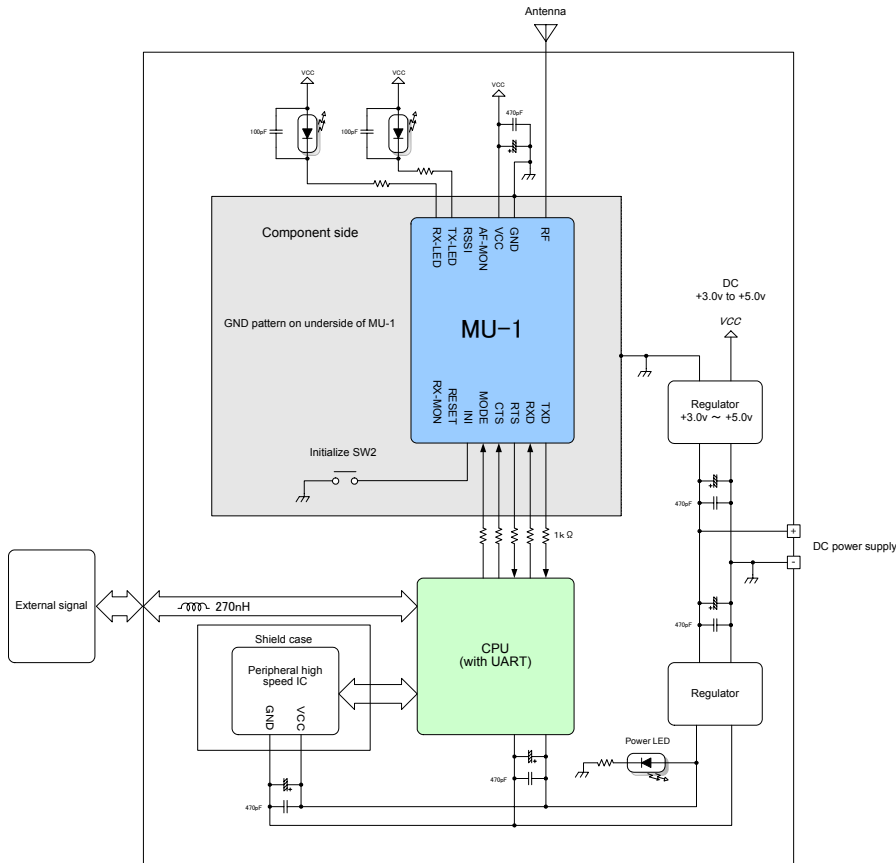
■ Connecting to a single-chip microcomputer (RS232C level connection)

For connecting a single-chip microcomputer with RS232C level, a level conversion IC is required for both.

Example: Using MU1-RIK
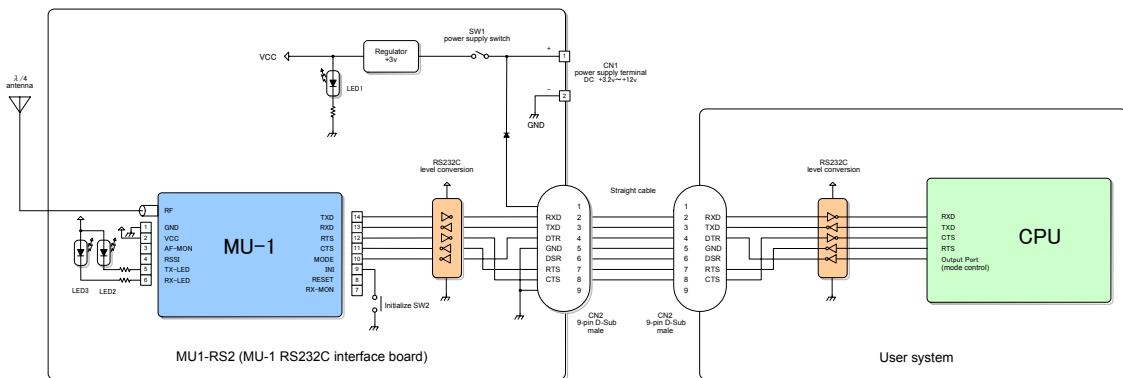
* You can supply power from the D-Sub connector pin No.1.

* When using the Evaluation Program, it is necessary to set the DSR signal line to High level.

CIRCUIT DESIGN, INC.

Mounting the Unit

② Mount a 1 kΩ resistor near the MU-1 in/output pin, and connect it to the digital circuit

⑧ Make and connect many through holes in the circuit board overall in the GND pattern on the component side and solder side in order to lower the impedance.

⑦ In order to make contact between the GND of the circuit board overall and the storage case (or wiring or metal plate), provide a GND pattern below the attachment screws. Determine the ground connection point by measuring the radiation level and field noise level.

The antenna length is λ/4

⑤ Provide a very long GND pattern for the antenna and the opposite direction. The ideal length is 17.5 cm with a 434 MHz MU-1 with λ/4 wavelength. If it is shorter, the antenna radiation rate is reduced, the range is reduced, and communication stability is negatively affected. If it is not physically possible to achieve a sufficiently large ground, use the case, wiring, or metal plate as a ground.

⑥ If there are ICs or the like operating at high speed and radiating noise in the vicinity of the MU-1 , cover them with a shield case. Also use a 4-layer circuit board and provide GND patterns on the solder side and component side. Use an internal layer for the signal line.

④ Use at least a double-sided circuit board, and design GND pattern as large as possible In addition, rather than using single point grounding, use a ground plane. The ground plane (pattern) for the whip antenna of the MU-1 plays an important role.

① For the MU-1 power supply provide a dedicated power supply using a bi-polar low-noise 3-pin regulator.

ユーザー CPU

③ In the vicinity of the external signal in/output connector, mount a 270 nH inverter (self-resonant frequency of 500 MHz or more). (Toko LL1608-FSR27J or the like).

20 to 30 mm

Power supply line

⑨ In order to provide the power supply line with high frequency insulation, wrap it four times around a ferrite core. For the ferrite core, use a TDK HF40T or the like.

External signal line

⑩ Use shielded cable for the external interface line, and ground the shield to the external equipment.

* If it is not possible to avoid noise radiation from peripheral components or devices, make the circuit board with the MU-1 mounted on it the sub board, and locate it away from the noise source. In addition, consider using a shielding plate or wave absorber.

Component side

Solder side