Embedded low power radio modem

MU-4-434

434MHz



Operation Guide

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Chapter 1 The MU-4

1.1 Outline

The MU-4 is an embedded low power radio modem for transmission of serial data. Since it is possible to control the radio component using dedicated simple commands, the user can concentrate on developing the transmitting and receiving programs for their system. For communication protocols, the MU-4 has a standard protocol common to Circuit Design's MU series and an error correction protocol which performs error correction on the receiver side. Since the error correction protocol uses Reed-Solomon code*1 that has strong error correction ability even in environments prone to burst errors, the user can configure highly reliable systems compared to conventional radio modems. Transmitting and receiving data and issuing commands are performed using a UART*2 interface with a single-chip CPU and the modem can also be controlled via the COM port (RS232C format) of the computer, making it possible for the user to develop systems quickly*3.
In addition, using a maximum of 10 relay stations, it is possible to gather data from and control equipment in remote locations. The MU-4 is designed to minimize design difficulties involving high frequency components, so that the user can embed the modem in their system with peace of mind.

☞ **Important**
It is not possible simply to replace communication using existing RS232C system equipment connected with a cable, with MU-4 wireless communication. In order to build wireless systems, issues specific to radio communications must be solved. The hardware and software must be newly designed specifically for the MU-4.

*1 Forward error correction code used for compact discs, hard disks and satellite communications
*2 UART (Universal Asynchronous Receiver Transmitter)
*3 Development kits such as MU4-RS2(RS232C interface board), MU4-USB(USB interface board) are available

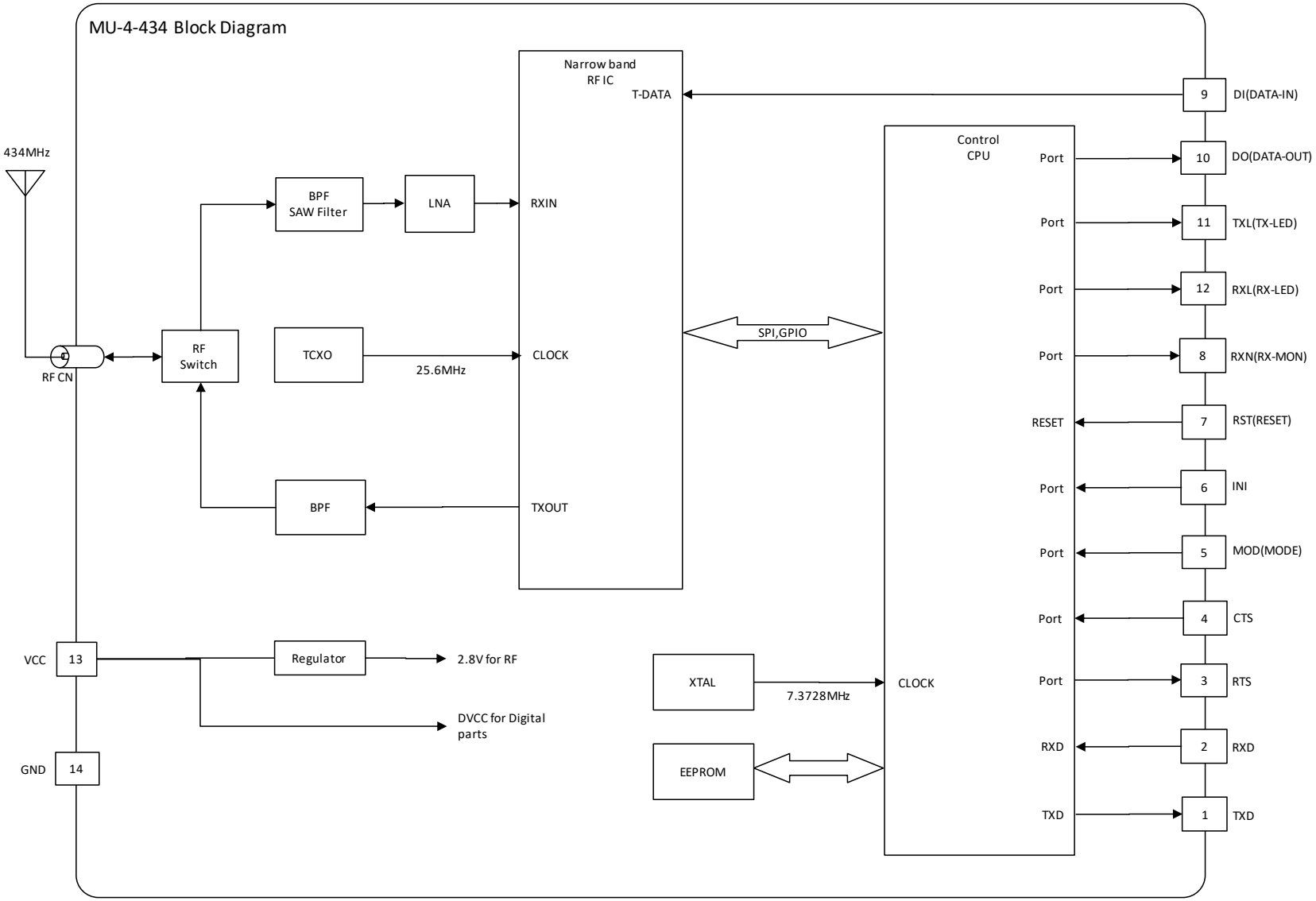
1.1.1 Features

- RED compliant
- RF control and serial data transmission with a simple system of commands
- Strong error correction using Reed-Solomon code
- Long distance communication using a maximum of 10 relay stations
- Communication protocol common to an MU series
- N:N system possible by setting User/Group/Equipment IDs
- Radio and field status assessment using RSSI acquisition commands
- Transparent mode in which user's own protocol can be used

1.1.2 Applications

- Serial data transmission
  Energy monitoring, data monitoring devices, handy terminals, barcode readers, housing equipment control
- Telecontrol
  Various warning systems, remote control for construction machinery, display devices, motor control, lifters
  Remote control of FA equipment
- Telemetry
  Security systems, water level monitors for rivers and dams, temperature and humidity gauges, rain gauges, pressure gauges, voltmeters, ampere meters

1.2 Block Diagram



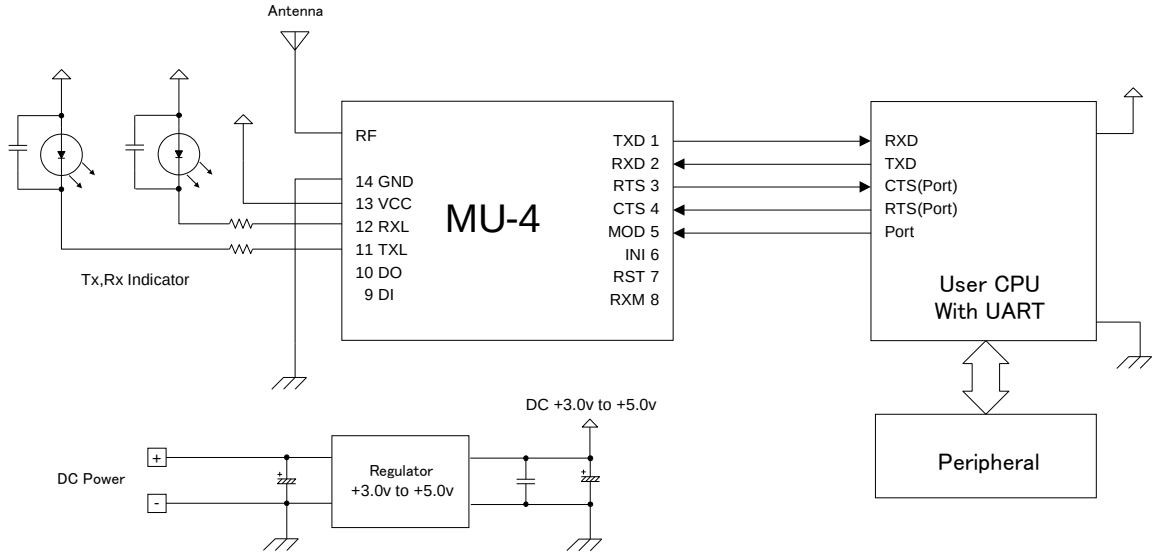
1.3 Example of the Control Method

The VCC terminal of the MU-4 is connected directly to the power source of the mounted CPU. Ensure that the voltage of the power supply is regulated to within DC +3.0 v to +5.0 v.
Basically the MU-4 uses hardware flow control with RTS or CTS, however 3-line control can be used without the hardware flow control. In this case, set the CTS terminal to Low level. In addition, care is required with the timing of transmitting and receiving.

Example 1 and Example 2 are basically the same methods except for the difference in control voltage.

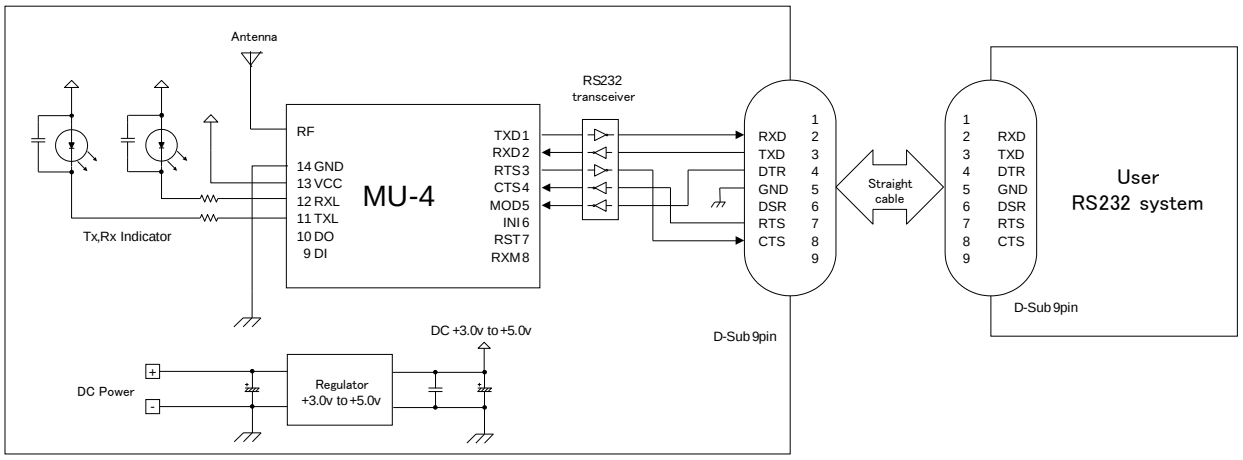
1.3.1 Example 1: Controlling the MU-4 with the on-board CPU

It is possible to interface the MU-4 directly using the UART interface of the on-board CPU.



1.3.2 Example 2: Controlling the MU-4 via RS232C

1. Using the RS232 port of your computer, you can develop a new program for OS's such as Windows and the like. In this case, use an RS232C transceiver. (The program for existing system equipment will not work.)
2. By supplying power to the MU-4 with a cable, you can also isolate the radio component from your system and locate it in the most suitable environment. The distance can be extended by 15 m to 50 m, but the exact distance should be confirmed through experiments.



* To use the Evaluation Software Program, the DSR signal line should be set to High level.
* When hardware flow control is not used, connect the RTS and CTS at RS232C level.

Chapter 2 Specifications and Diagram

2.1 Main Specifications

2.1.1 General specifications

Temperature conditions: +25ºC ± 5ºC, typical

Item	Specification	Remarks
Compatible standards	EN 300 220	CE mark
Emission class	F1D	
Antenna power (selectable)	Within 10 mW or 1 mW	+5ºC to +35ºC Contact (50 Ω) Selectable by the command
Frequency stability	Within ± 4 ppm	Reference freq. at 25ºC
Antenna	1/4λ wire antenna	Gain of 2.14 dBi or less
Communication method	Half-duplex, one-way, broadcast	
Modulation system	Binary FSK	
Oscillation system	PLL synthesizer system	
Radio communication speed	4800 bps	
Frequency range	433.2000 to 434.7750 MHz	
Channel spacing	12.5 kHz	
Number of channels	127	Channel step 12.5 kHz
Receiver spurious radiation	-57 dBm or less (<1GHz) -47 dBm or less (>1GHz)	
Receiver sensitivity	-113 dBm	Transparent mode (BER 0.1%)
Operating temperature	-20ºC to +65ºC (No dew condensation)	The operation distance varies with the temperature conditions.
Storage temperature	-25ºC to +70ºC (No dew condensation)	
Operating voltage	3.0 V to 5.0 V	Absolute maximum rated voltage 5.5 v
Consumption current	At 10mW: TX 42 mA max. RX 22 mA max. At 1 mW: TX 26 mA max. RX 22 mA max.	When the supply voltage is 3 v
Number of EEPROM conversions	1,000,000 times	
Error correction system	Reed-Solomon code	RS (255, 247)
External dimensions	36 mm × 26 mm × 8 mm (W × D × H)	Not including the antenna. H is the height from the mounting surface.
Unit weight	14.5 g	

Reference data

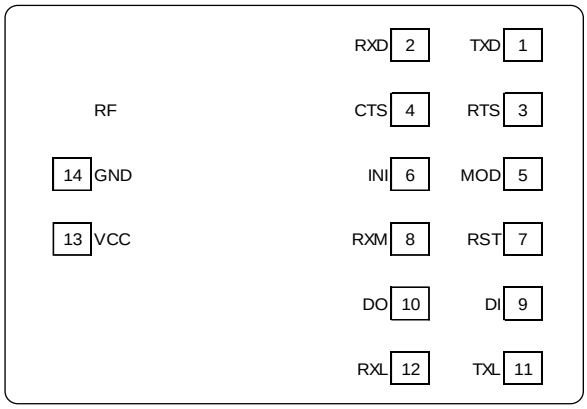
* Effective radio communication speed: About 3,400 bps / Conditions: One-way communication, no error correction, 25ºC
* Range: About 600 m / Conditions: One-way communication, no error correction, 25ºC, line of sight distance, ground level of 1.5 m, vertical antenna

2.1.2 UART interface specifications

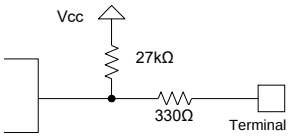
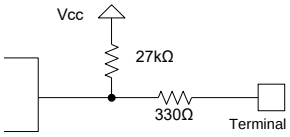
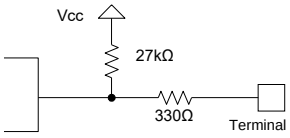
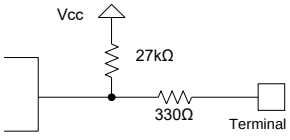
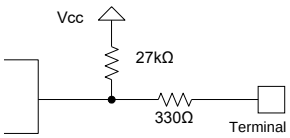
Communication method	Serial communication (RS232C format)
Synchronization	Start-stop (asynchronous)
Data speed	1,200 / 2,400 / 4,800 / 9,600 / 19,200 / 38,400 / 57,600 bps
Flow control	RTS/CTS hardware flow control
Other parameters	Data length (8 bits), Parity (None, Even, Odd), Stop bits (1 or 2)

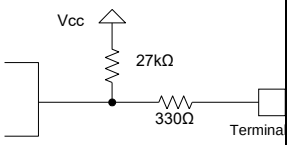
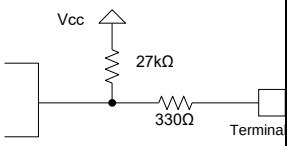
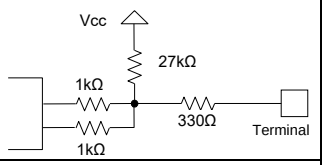
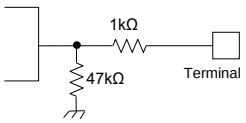
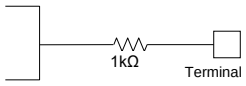
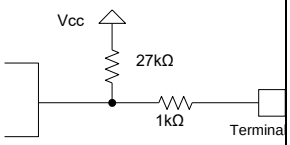
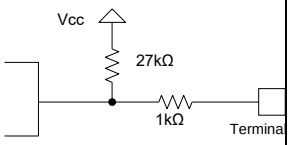
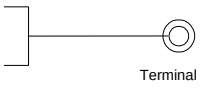
2.2 Terminal Specifications

MU-4 terminal number and name (Top View)



- Level conversion is required for connection to RS232. The RS232C DSR signal must be supported by the user's circuit board.
- Unused terminals should be set to open.
- The thresholds for Low level and High level are VCC × 0.2 and VCC × 0.8 respectively, based on the supply voltage VCC.
- When using the MU-4 with its power line disconnected, please set the CPU ports to a high-impedance state to prevent current leakage from the ports connected to the CPU.

Terminal No.	Terminal name	I/O	Description	Internal circuit
1	TXD	O	The serial data transmit terminal.	
2	RXD	I	The serial data receive terminal.	
3	RTS	O	The hardware flow control signal output terminal. If the internal status is not busy, the status is Low and data can be received via the RXD terminal. If the internal status is busy, the status is High and data cannot be received.	
4	CTS	I	The hardware flow control signal input terminal. Determines that the unit is not busy when the status is Low, and sends data from the TXD terminal. Determines that the unit is busy when the status is High, and does not send data.	
5	MOD (MODE)	I	Switches between the command mode, binary mode, or text mode. In the command mode when set to High, and the binary mode or text mode when set to Low.	

Terminal No.	Terminal name	I/O	Description	Internal circuit
6	INI (INITIALIZE)	I	The terminal for initializing the CPU internal settings. The settings are initialized if the power is turned on in the Low state. The default values are enabled when the power is switched on again.	
7	RST (RESET)	I	The CPU reset terminal. Setting this terminal to Low level for a period of 1 ms resets the internal CPU. This should normally be set to open.	
8	RXM (RX-MON)	O	A test terminal for monitoring the internal status with an oscilloscope when receiving data. Normally this should be open and only be used by the manufacturer.	
9	DI (DATA-IN)	I	Transmission data input terminal in the transparent mode. After setting the transparent mode, input the transmission data of 4800 bps. Set to open when the transparent mode is not used.	
10	DO (DATA-OUT)	O	Reception data output terminal in the transparent mode. Outputs the received data of 4800 bps. Set to open when the transparent mode is not used.	
11	TXL (TX-LED)	O	The terminal for the transmission monitor LED. On when data is transmitted. The signal line includes an internal 1 kΩ resistor. With external resistors, ensure that the LED current is within 1 mA. In addition, add a ceramic capacitor of about 100 pF in parallel with the LED.	
12	RXL (RX-LED)	O	The terminal for the receiving monitor LED. On when valid data is received. The signal line includes a 1 kΩ internal resistor. With external resistors, ensure that the LED current is within 1 mA. In addition, add a ceramic capacitor of about 100 pF in parallel with the LED.	
13	VCC	I	The power supply terminal. Provide a regulated power source with a supply voltage of DC +3.0 V to +5.0 or less. Applying a voltage higher than the rating will damage the semiconductor of the unit. An inrush current occurs to charge the capacitor of approx. 2 uF.	
14	GND	I	GND	
-	RF	I/O	The antenna terminal.	

* The terminal specifications may change without prior notice.

2.3 Channel Table

The frequency channels that the MU-4 can use are channels 1 to 127 in the 434 MHz band.
To set the channel, use the command format '@CH + channel number'.

Example: Set channel 15 as the channel to use.
Specify the channel following '@CH' with 2 ASCII (hexadecimal) characters.

Control command: @CH 0F CRLF
Control response: *CH = 0F CRLF

* : Default channel

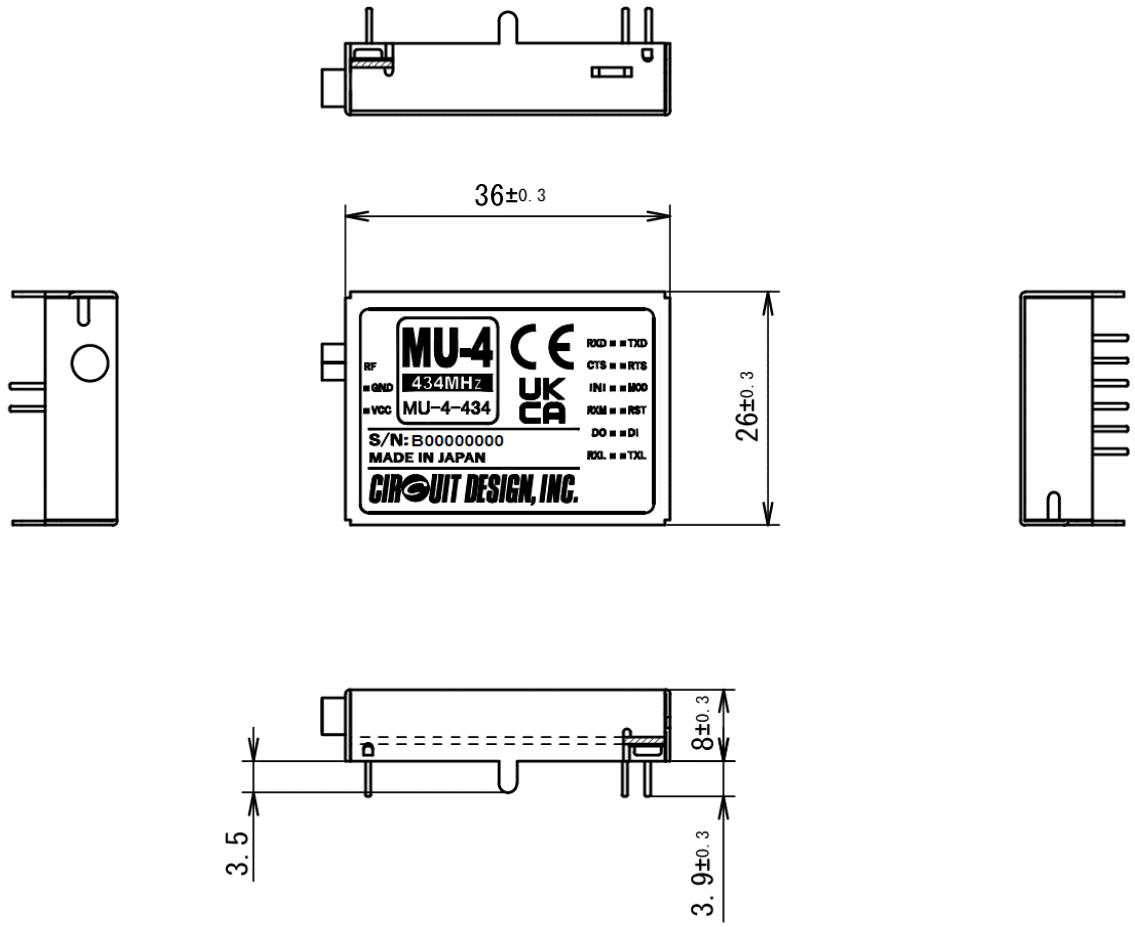
Channel	Frequency	Channel	Frequency	Channel	Frequency
Dec. (Hex)	MHz	Dec. (Hex)	MHz	Dec. (Hex)	MHz
		20(14)	433.4375	40(28)	433.6875
1(01)	433.2000	21(15)	433.4500	41(29)	433.7000
2(02)	433.2125	22(16)	433.4625	42(2A)	433.7125
3(03)	433.2250	23(17)	433.4750	43(2B)	433.7250
4(04)	433.2375	24(18)	433.4875	44(2C)	433.7375
5(05)	433.2500	25(19)	433.5000	45(2D)	433.7500
6(06)	433.2625	26(1A)	433.5125	46(2E)	433.7625
7(07)	433.2750	27(1B)	433.5250	47(2F)	433.7750
8(08)	433.2875	28(1C)	433.5375	48(30)	433.7875
9(09)	433.3000	29(1D)	433.5500	49(31)	433.8000
10(0A)	433.3125	30(1E)	433.5625	50(32)	433.8125
11(0B)	433.3250	31(1F)	433.5750	51(33)	433.8250
12(0C)	433.3375	32(20)	433.5875	52(34)	433.8375
13(0D)	433.3500	33(21)	433.6000	53(35)	433.8500
14(0E)	433.3625	34(22)	433.6125	54(36)	433.8625
15(0F)	433.3750	35(23)	433.6250	55(37)	433.8750
16(10)	433.3875	36(24)	433.6375	56(38)	433.8875
17(11)	433.4000	37(25)	433.6500	57(39)	433.9000
18(12)	433.4125	38(26)	433.6625	58(3A)	433.9125
19(13)	433.4250	39(27)	433.6750	59(3B)	433.9250

Channel	Frequency	Channel	Frequency	Channel	Frequency
Dec. (Hex)	MHz	Dec. (Hex)	MHz	Dec. (Hex)	MHz
60(3C)	433.9375	85(55)	434.2500	110(6E)	434.5625
61(3D)	433.9500	86(56)	434.2625	111(6F)	434.5750
62(3E)	433.9625	87(57)	434.2750	112(70)	434.5875
63(3F)	433.9750	88(58)	434.2875	113(71)	434.6000
64(40)	433.9875	89(59)	434.3000	114(72)	434.6125
65(41)	434.0000	90(5A)	434.3125	115(73)	434.6250
66(42)	434.0125	91(5B)	434.3250	116(74)	434.6375
67(43)	434.0250	92(5C)	434.3375	117(75)	434.6500
68(44)	434.0375	93(5D)	434.3500	118(76)	434.6625
69(45)	434.0500	94(5E)	434.3625	119(77)	434.6750
70(46)	434.0625	95(5F)	434.3750	120(78)	434.6875
71(47)	434.0750	96(60)	434.3875	121(79)	434.7000
72(48)	434.0875	97(61)	434.4000	122(7A)	434.7125
73(49)	434.1000	98(62)	434.4125	123(7B)	434.7250
74(4A)	434.1125	99(63)	434.4250	124(7C)	434.7375
75(4B)	434.1250	100(64)	434.4375	125(7D)	434.7500
76(4C)	434.1375	101(65)	434.4500	126(7E)	434.7625
77(4D)	434.1500	102(66)	434.4625	127(7F)	434.7750
78(4E)	434.1625	103(67)	434.4750	-	-
79(4F)	434.1750	104(68)	434.4875	-	-
80(50)	434.1875	105(69)	434.5000	-	-
81(51)	434.2000	106(6A)	434.5125	-	-
82(52)	434.2125	107(6B)	434.5250	-	-
83(53)	434.2250	108(6C)	434.5375	-	-
84(54)	434.2375	109(6D)	434.5500	-	-

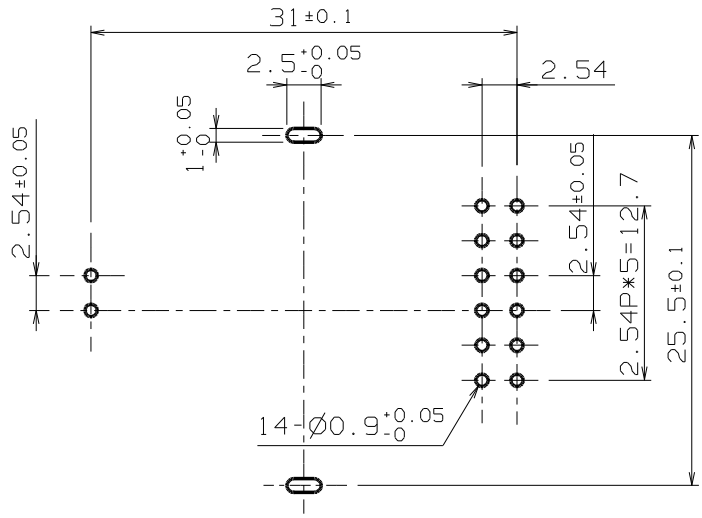
* The number of channels which can be used at the same time in the same area is at most 8 to 11 due to the third-order intermodulation or near-far problem.
* The image frequency occurs at the frequency of ‘receiving frequency - 800kHz’ and may degrade the blocking characteristics of the MU-4. Please take this into account when making a channel plan.

2.4 Dimensional Drawing

2.4.1 External dimensions



2.4.2 Diagram of dimensions for hole positions



Top view

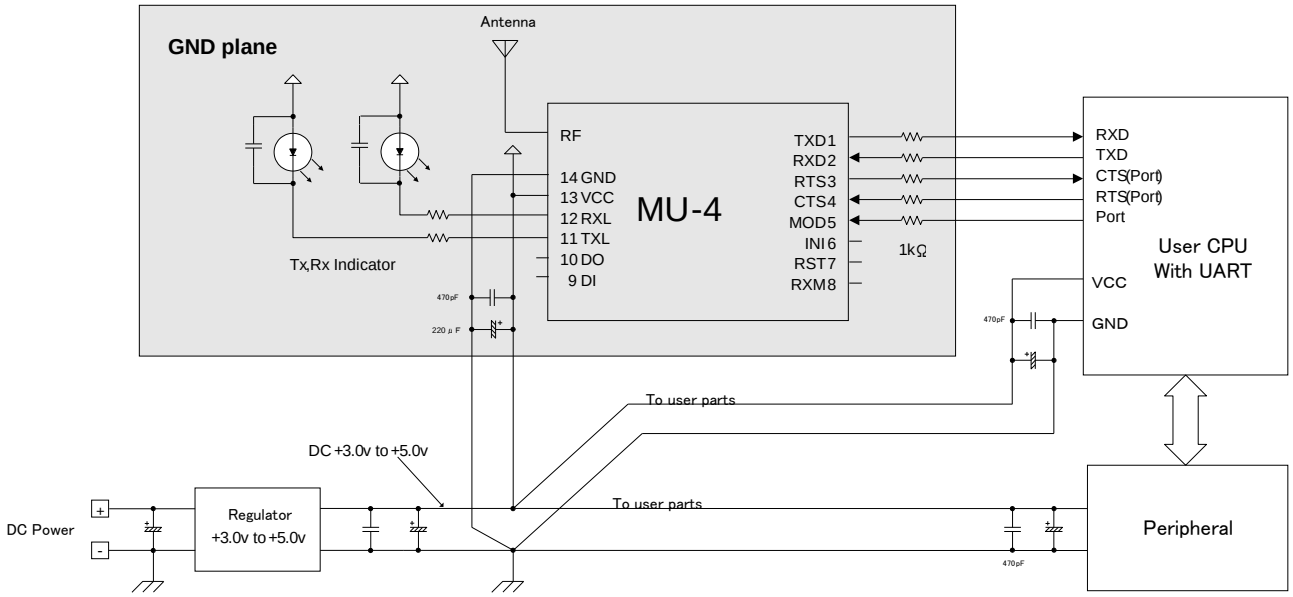
Chapter 3 How to Design a User System

3.1 Circuit Board Design

When embedding this unit in a user system, pay due attention to the design of the board and case.

1. The power supply used for the MU-4 must be a DC regulated power source, with a voltage span of +3.0 v to +5.0 v. A current of about 40 mA is required when transmitting. Ensure that the voltage of the MU-4 and user system CPU are the same.
   Although a regulated voltage is supplied to the internal high frequency component, in order to support the voltages of a variety of user systems, the power supply for the CPU is connected directly to the VCC terminal. For this reason, care is required to achieve the correct voltage range.
2. Add a 1 kΩ resistor or 0.33 µH inductor to the UART related control signal line. This should be inserted close to the connector pins.
3. When attaching this unit to a circuit board, use a double sided circuit board if possible. On the top surface of the board, make a sufficient area beneath the MU-4 for the ground pattern (GND plane), and use the bottom surface of the board for signal lines.
4. If the MU-4 power supply line is used jointly with the power supply lines of other circuits in the system (such as the CPU), it may cause malfunctions, and the unit may not perform properly.
   For the power supply of the MU-4, always use a separate line from the system power circuit, and install bypass capacitors at the receiving point.
5. It is possible to directly connect LEDs to the LED terminals, however ensure that the LED current is limited to 1 mA or less.

   Blinking of the LEDs may affect communication. It is recommend that ceramic capacitors of about 100 pF are added in parallel to the LEDs.
6. Do not connect anything to RXM terminal.
7. Make the signal lines to this unit as short as possible.



3.2 Miscellaneous

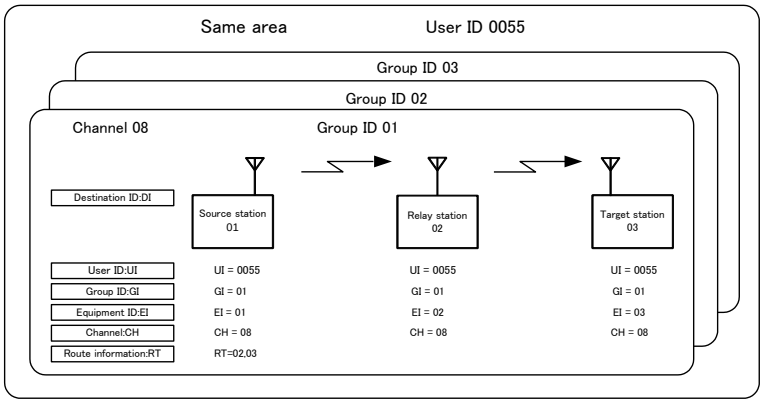
1. Devise ways of isolating the MU-4 as far as possible from sources of noise, including from other embedded equipment.
2. Arrange the MU-4 so that it will not be covered by the operator's hand or the like.
3. The MU-4 does not have a waterproof structure. If the antenna is located outside the main unit, use a structure that prevents water droplets from entering the case.

Chapter 4 How to Use the MU-4

4.1 Communication Concept

4.1.1 Station types and link parameters

When performing communication using the MU-4, the source station transmits data towards the target station. If necessary, it is also possible to relay data using relay stations between the source and target stations. In addition, to avoid collisions with, and to ensure independence from other systems, it is necessary to set the link parameters to identify the system and each station.



1. The source station, relay station and target station

- **Source station** The station that transmits data
- **Relay station** A station to relay data to the target station. The relay station neither buffers nor resends data but simply relays it directly to the target station. Setting is possible up to a maximum of 10 relay stations.
- **Target station** The station that receives data. The target station outputs the received data to the user controller. It also sends ACK data and RSSI (received signal level) data to the source station depending on the command issued from the source station.

2. The link parameter

In order to establish communication between the radio stations, it is necessary first to set the link parameters.

- **UI: User ID**
  An ID given to the MU-4 user for identification of the user.
  If all the equipment within the user system is not set to the same User ID, no link will be made.
- **GI: Group ID**
  An ID to identify the group within the user system. Set the same Group ID for all radio stations within the group.
- **EI: Equipment ID**
  An ID given to each unit for identification of each station. The data transmit command transmits data to the Equipment ID set as the route information or Destination ID
- **DI: Destination ID**
  Specifies the Equipment ID of the target station when no relay station is used in the system.
- **RT: Route information**
  Route information to the target station in the system using relay stations. List the route information in the route register or transmit a command character string.
- **Channel**
  If all stations in a system are not set to the same channel, no link will be made.

4.1.2 Basic data transmission

When user data is transmitted from the source station towards the target station using data transmit commands, a character string including the data (data receive) is output from the target station and processed by the program of the user controller.

Example 1 1:1 (1:N) system not using the relay function

When the source station 5F transmits the 5 bytes of data 'ABCDE' to the target station 01
The diagram below shows the case in which the data transmit command 1 is issued.



・Initial setting

①Set all stations to the same User ID, Group ID and channel

②Set a different number to each equipment as the Equipment ID (EI)

・Source station 5F status

③Set the Destination ID(DI)

④Issue the data transmit command 1
@DT 05 ABCDE CRLF

⑤Data transmit response
＊DT=05 CRLF

⑥Send data

・Target station 01status

⑦Data receive 1
＊DR=05 ABCDE CRLF

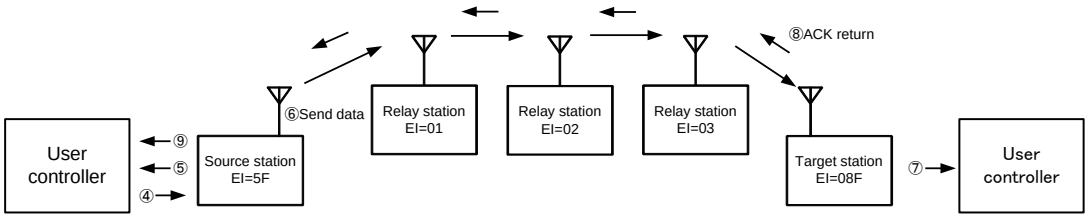
Example 2 System using the relay function

When the source station 5F transmits the 10 bytes of data '0123ABC$#4' to the target station 8F via relay stations 01, 02 and 03

With 1:N communication not using relay stations, the route is specified using the Destination ID command '@DI' at the source station. However when relay stations are used, data can be relayed using one of the following.

1. Set the route information in the route register using the '@RT' command to specify the relay route.
2. Enter the route information directly at the end of the data transmit command '@DT'.

When performing two-way communication, it is necessary to confirm if the data transmitted from the source station is received at the target station without error. The MU-4 has a data transmit command that requests the target station to return the data receive acknowledgment 'ACK'. The diagram below shows a case in which relay stations are used and the data transmit command 2 with ACK is issued.



・Initial setting

①Set all stations to the same User ID, Group ID and channel

②Set a different number to each equipment as the Equipment ID (EI)

③Set the route information in the route register of the source station

・Source station 5F status

④Issue the data transmit command 2
@DT 0A 0123ABC$#4 /A CRLF

⑤Data transmit response
*DT=0A CRLF

⑥Send data

⑨ACK response from the target station
*DR=00 CRLF (issued after the delay time has elapsed)

・Target station 8F status

⑦Data receive 2
＊DR=0A 0123ABC$#4 CRLF

⑧ACK return

4.1.3 The data transmit command

The MU-4 has 3 data transmit commands.

1. Data transmit command 1 2. Data transmit command 2 3. Data transmit command 3

The user can freely decide the format for the data part of the data transmit command. Using data transmit command 3, the received signal level of the received packet data is included at the front of the receiving data (data receive), which is useful for determining the transmission route and so on.
The same can be done with the data transmit command 2 by setting the '@SI' command.

When actually developing a system program, in addition to the transmission process of the user system data such as temperature data and display data, it is necessary to perform various controls. By choosing the transmit command to use depending on the system configuration, it is possible to simplify design of the system protocol and make an easy-to use program.

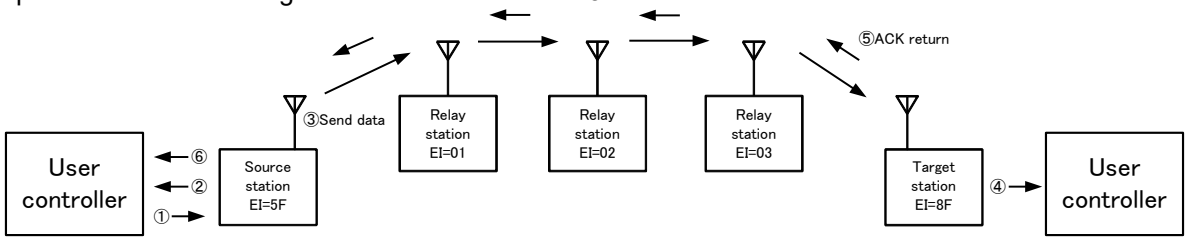
1. Data transmit command 1
The most basic transmission command mainly used for 1:1 (1:N) systems not using relay stations.

2. Data transmit command 2
A data transmit command for systems using relay stations. It can also be used for 1:1 (1:N) systems not using relay stations.
Command option character for data transmit command 2: '/'
Target station output characters (Data receive): '*DR'

3. Data transmit command 3
A data transmit command for systems using relay stations. It can also be used for 1:1 (1:N) systems not using relay stations.
The received signal strength (RSSI) of the received packet data is included at the front of the data receive at the target station.
Command option character for the control transmit command 3: '%'
Target station output characters (Data receive): '*DC'

With the data transmit commands 2 and 3, the method of command notation on the program is different depending on the following cases.
1. Transmission based on route information preset in the route register.
2. Transmission based on route information directly entered in the transmit command.

Example: Transmission using data transmit command 3



・Source station 5F status

①Issue the data transmit command 3
Format 1:@DT 0A 0123ABC$#4 %A 01,02,03,8F CRLF
Format 2:@DT 0A 0123ABC$#4 %A CRLF

②Data transmit response
*DT=0A CRLF

③Send data

⑥ACK response
*DC=45 00 CRLF (issued after the relay time has elapsed)

・Target station 8F status

④Data receive 3
When RI=OF *DC=45 0A 0123ABC$#4 CRLF(Default)
When RI=ON *DC=45 0A 0123ABC$#4 /R 5F,01,02,03 CRLF

⑤ACK return

Transmit the 10 bytes (0Ah) of data '0123ABC$#4' to the target station ID = 8F via the relay station IDs = 01, 02, 03. Source station Equipment ID = 5F.

* '45h' at the front indicates the signal level of the received packet. In this case, it is -69 dBm (45h).
For details of the value, refer to the 'RA' command.

4.1.4 The link parameters

In order to transmit and receive data, the MU-4 has the following link related parameters.
Link parameters can be specified easily with commands, and they can be changed each time data is sent.
In addition, if the source station, relay station, and target station do not all use the same channel, no link will be made.

1. UI: User ID, 16-bit, 0000h to FFFEh (0000h is the ID for testing, and FFFFh cannot be used)
The User ID is an ID given to the MU-4 user for identification of the user system. Communication is not possible unless all equipment within the user system is set with the same User ID. If a user configures multiple systems, use the Group ID for identification. The User ID setting command is '@UI + User ID + password'. The product default User ID is 0000 and this can be used as it is when no particular User ID is required. However, we recommend that you set a User ID to prevent radio interference within a given area.
If you require a User ID, please contact Circuit Design, Inc. The 16 User IDs listed in the explanation of User ID command can be used freely.

2. GI: Group ID, 8-bit, 00h to FFh
The Group ID is an ID to identify the group within the user system. Set the same Group ID for all equipment within the group. Maintain Group IDs as identification numbers when building other systems. The setting command is '@GI'.
Please contact Circuit Design, Inc. in cases where use of Group IDs is insufficient and you require other User IDs.

3. EI: Equipment ID, 8-bit, 01h to FFh (FFh is a special operation)
The Equipment ID is an ID for identification of each radio unit. At the source station, enter the Equipment ID of the target station at the end of the route information or as the Destination ID to which to transmit data.
At the target station, the Destination ID included in the received packets is automatically compared with the local station EI. The setting command is '@EI'.

4. DI: Destination ID, 8-bit, 00h to FFh (00h and FFh are special operations)
This is used to specify the Equipment ID of the target station in a system not using relay stations. The setting command is '@DI'. If 00 (DI = 00h) is specified as the Destination ID and data transmit command 1 is issued, all equipment within the same group receives the data at the same time, irrespective of the Equipment ID (Broadcast). If DI = FFh is specified, the data is sent but no station will receive it.

5. RT: Route information
This indicates the route to the target station.
The route information lists the Equipment IDs of the relay stations and the Equipment ID of the target station in the route register or data transmit command character string. The route information is used with data transmit commands 2 and 3. There are two ways to transmit data as follows.
- Transmission based on route information set in the route register with the '@RT' command
- Transmission with the route information entered directly in the data transmission command

If only one station is specified in the route information, that station is the target station.

6. Channel
If all stations in a system are not set to the same channel, no link will be made.

4.1.5 Conditions for establishing a link

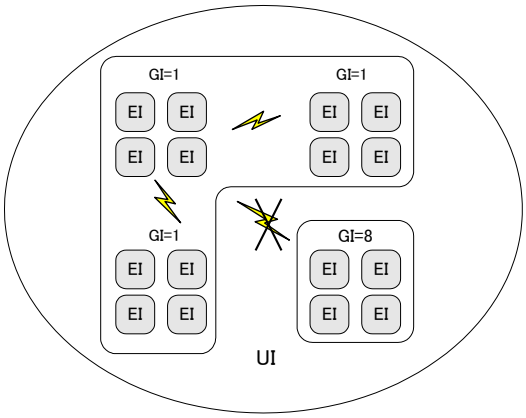
A link is established for communications when the following conditions are met simultaneously.
1. There are no errors in the received packet
2. The User ID and Group ID match
3. The Equipment ID specified in the route information or Destination ID and the Equipment ID of the target station match
4. The channel used is the same

4.2 System Configuration (When the Relay Function is Not Used)

The MU-4 can be used for building 1:1, 1:N, and N:N systems. Several systems can be operated within the same area by separating the channels used.
Equipment IDs from 01h to FEh can be specified, and a maximum of 254 MU-4 units can be connected in 1 group.
With 1:1 (1:N) communication, the Destination ID is specified and data is transmitted with data transmit command 1, however in this case set the route register to “relay function disabled = ‘NA’” using the ‘@RT’ command.

4.2.1 Communication within a group (1:N and N:N systems)

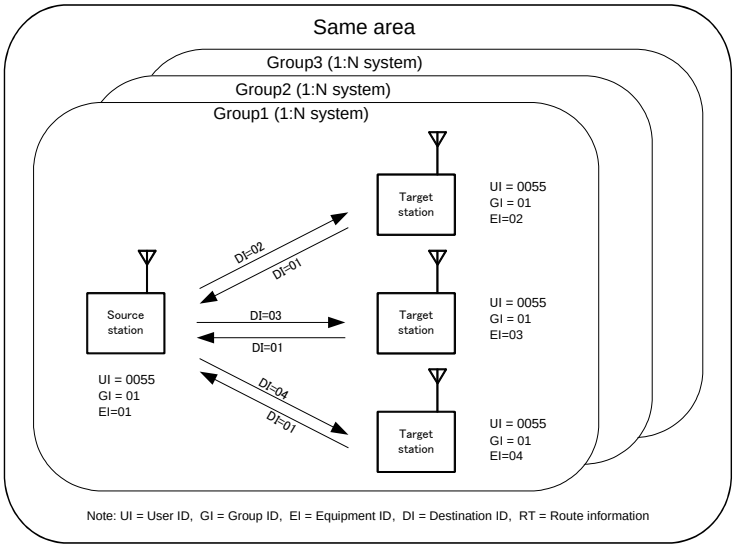
Set the same User ID and Group ID for one group. If the Destination ID specified at the source station and the Equipment ID of the target station match, data (data receive) is output from the target station.
The diagram below shows a 1:N system, although it is also possible to build an N:N system in which all the units have an equal relationship.



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

Item name		Size	ID 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.



◇ Communication between groups

By changing the Group ID for transmitting, it is possible to communicate with another group.

◇ Broadcast communication

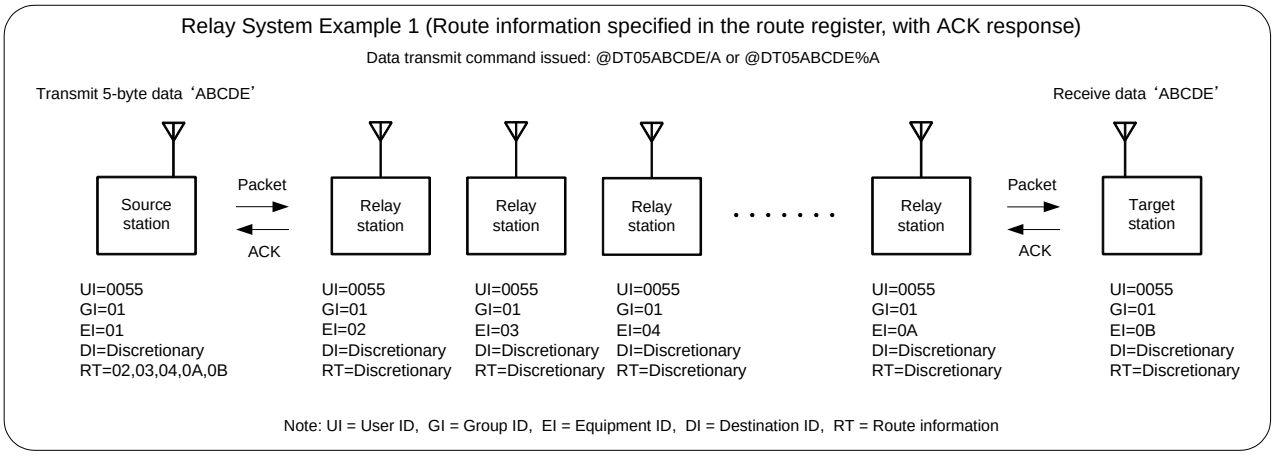
If the Destination ID is specified as 00h at the source station and data is transmitted, all target stations will receive the data at the same time, irrespective of the Equipment ID.

4.3 System Configuration (When the Relay Function is Used)

With 1 hop communication, the Destination ID is used as a link parameter. However with multi-hop communication using the relay function, data is transmitted based on the route information set in the route register with the '@RT' command or based on route information entered directly in the '@DT' command. When using the relay function, use data transmit command 2 or 3.
The MU-4 relay function does not perform retry between each station for data. The data from the source station is transmitted at once through to the target station. When reliability is required for data transmission, use the '@DT' command (/A, /B, %A, %B command options) that has an ACK response. It is possible to set a maximum of 10 relay stations.

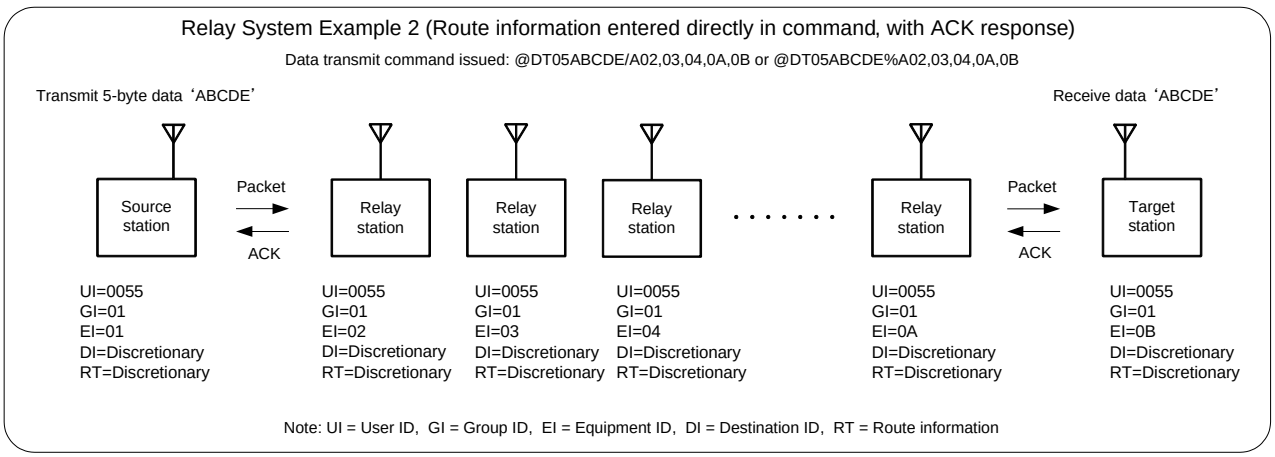
4.3.1 Transmission with the route register route information

The diagram below is an example of transmission based on route information set in the route register. Route information is set only in the source station. In this case, use only the command option '/A' or '%A' for the '@DT' command.



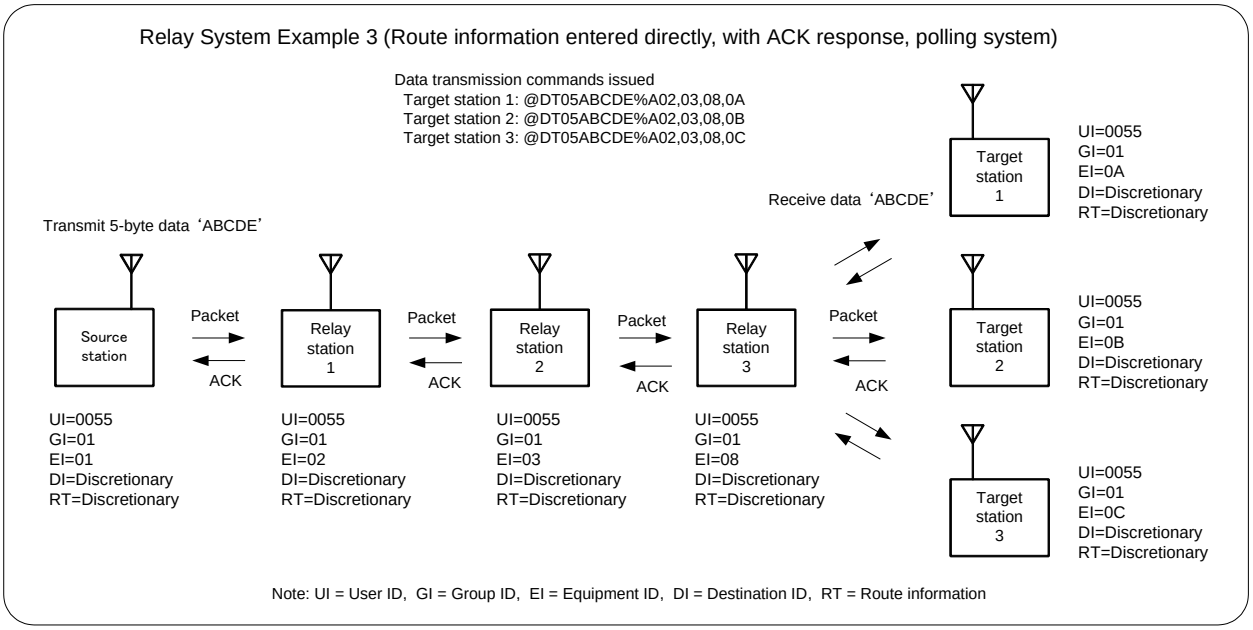
4.3.2 Transmission with the route information entered in the transmit command

The diagram below is an example of transmission with the route information entered directly in the command option line of the '@DT' command. Enter the route information in the '@DT' command issued after '/A' or '%A'. In this case, the route information set in the route register is ignored.



4.3.3 1:N relay system

The diagram below shows a 1:N system using the relay function, in which communication is performed with several target stations at a remote location.
In the diagram, the route information is entered directly in the transmit command, however communication is also possible using the route register content.



Broadcast communication
If data is transmitted after Equipment ID = 00h as the last number in the route of the source station route information settings, all target stations receive the data at the same time, irrespective of the Equipment ID.
The command for the system in the diagram above is as follows.

Control transmit command 3: @DT 05 ABCDE %R 02,03,08,00

However, note that the data is transmitted in a range to which the radio waves reach from the last relay station (relay station 3). In other words, relay station 2 also receives the data at the same time.
Also, do not use commands with ACK responses (command options: /A, /B, %A, and %B) in the transmit command since these cause radio wave collisions.

4.4 Modes

The MU-4 has the following 3 modes.
1. Command mode (standard mode)
2. Text mode (for testing)
3. Binary mode (for testing)

Transmitting and receiving data is usually performed in the command mode. Use this mode when you build your system. The text mode and binary mode are provided as testing modes, however you can also make applications within the range of these functions.

Note

When configuring your system, ensure that the source station and target station are in the same mode. In addition, ensure that the relay function is used in the command mode.

4.4.1 Command mode

This is the basic mode for sending and receiving user data by radio.
The MU-4 commands consist of commands for transmitting and receiving data, and commands for control of the parameters of the MU-4 unit itself. Changing the parameters, mode, and channel of the main unit cannot be performed in the binary mode or text mode. Consider how to enable mode switching at the hardware design stage. Control of the radio component is performed automatically by the MU-4, so you do not need to pay attention to this aspect.

255 bytes of user data can be sent at one time.
It is convenient to use data transmit commands 1 and 2 for transmission of user system data and data transmit command 3 if control is needed to transmit the data. The user can freely decide the format of those transmit commands.
With transmit commands 2 and 3, it is possible to request return of an 'ACK signal' to show that the data is correctly received at the target station. In addition, it is possible to output the same data from the relay station as from the target station. This makes it possible to synchronize the system.

When the MU-4 receives data, since only correctly received data is output to the user application as a data receive, it is processed on the user side properly.

4.4.2 Text mode (for testing)

This mode is used to check operation using RS232C communication software on a PC.
Text data can be input and output directly. This mode is convenient for transmitting and receiving characters entered using a keyboard. Always add the CrLf code as a terminator at the end of the character string. When the MU-4 detects this terminator, it starts data transmission. Ensure that the maximum number of characters input is within 255 bytes. The CrLf code (0Dh, 0Ah) and Esc code (1Bh) cannot be sent by radio. However, the CrLf code is attached to the end of the data output from the target station as a terminator.

4.4.3 Binary mode (for testing)

This mode is used to check operation using RS232C communication software on a PC.
All 8-bit codes (00h to FFh) can be transmitted and received as data. 255 bytes of binary data can be input or output directly at one time.
The input character string (max. 255 characters) is buffered until the buffer is filled with 255 characters, or until the value set for the period during which no data is input is reached, and the character string is framed and transmitted. The setting for the period during which no data is input is performed with the '@TB' command.

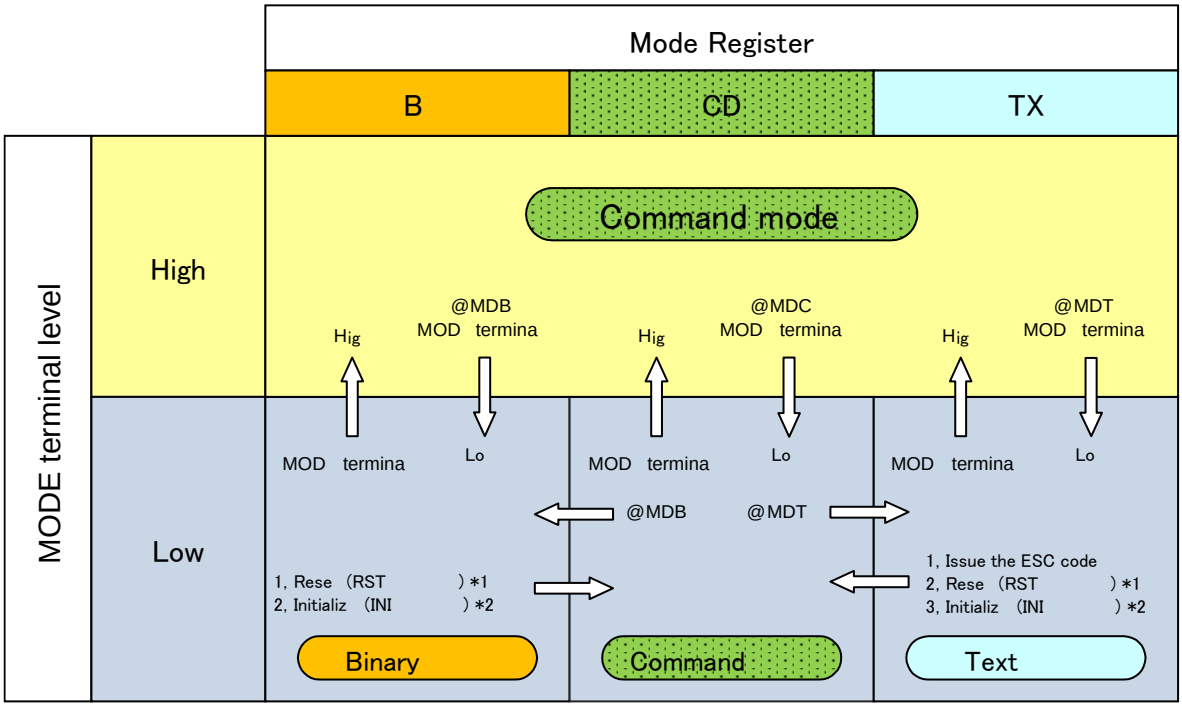
4.4.4 Mode setting

When the MODE terminal is at High level
The MU-4 is set to the command mode irrespective of the setting in the mode register. The recommended operation mode of the MU-4 is the command mode. When setting the MODE terminal to Low to switch to other modes, preset the mode register.

When the MODE terminal is at Low level
1. In the command mode if the '@MD TX' command is issued, the MU-4 mode register is set to 'TX', which is the text mode. Issuing the ESC code returns from the text mode to the command mode.

2. In the command mode if the '@MD BI' command is issued, the MU-4 mode register is set to 'BI', which is the binary mode. To switch from the binary mode to the command mode, turn off the power supply of the MU-4 briefly or reset the hardware.
   If the BI mode is fixed in the EEPROM using the command option '/W', the MU-4 cannot be set to the command mode without initializing it.
   To initialize the MU-4, set the INI terminal to Low and turn on the power, and after turning off the power briefly, set the INI terminal to High and turn on the power again.

3. By setting the MODE terminal to High level, the MU-4 can be set to the command mode whatever the setting in the MU-4 mode register (irrespective of the current mode).



*1: When the mode is set in the RAM *2: When the mode is fixed in the EEPROM

*** BI:** Binary mode **CD:** Command mode **TX:** Text mode

* The brackets ( ) in the diagram indicate use of an RS232C driver. When using RS232C communication software on a PC, the DTR line is always at H level and the MODE terminal is at L level.

4.5 Resetting

If you are uncertain about the various settings of the MU-4, return them to the settings at the time the power was turned on.

◆ The internal CPU is reset by any of the following.
1. Set the reset (RST) terminal of the MU-4 to 1 ms period Low level.
2. Issue the software reset command '@SR'.
3. The target station can be reset using an extended command.

4.6 Initializing

Return the unit to the factory default settings if communication with the MU-4 is not possible or if you are uncertain of the internal settings.

◆ The internal CPU is initialized with any of the following.
1. Set the INI terminal of the MU-4 to Low level and turn on the power. Then turn off the power, and after setting to the INI terminal to open, turn it on again.
2. Issue the initialize command '@IZ'. After issuing it, always issue the software reset command '@SR'.

◆ After initialization, the main parameter values (default values) are as follows. For details of the default values, refer to the relevant command in the manual.
1. Link parameters
   User ID: UI = 0000, Group ID: GI = 00, Equipment ID: EI = 01, Destination ID: DI = 01, Channel = 1 channel
2. UART parameters
   Baud rate = 19,200 bps, parity = none, stop bit = 1
3. Internal operation parameters
   Mode = command

4.7 Changing Channels

It is possible to change the channels used when the system is in operation.
This is done by changing the channels of the specified target station individually, or by changing the channels of all stations specified in the route information at once.
The channel changing function uses radio commands. Before changing the channel, always check that a data link is possible. However, since wireless errors may also occur in this case, changing the channel may not always be possible. Exercise prudence when changing channels.

4.8 Antenna Power Setting

The MU-4 is equipped with an antenna power switching function which can lower the antenna power (output power) from 10 mW to 1 mW. When communicating in a small area, setting the unit to 1 mW makes it possible to share radio wave resources effectively with many systems. To lower the power, issue the '@PW' command.

4.9 Communication Protocols

The MU-4 has a standard protocol and error correction protocols.
Of the error correction protocols, the interleave method has stronger error correction ability.

1. Standard protocol: A protocol normally used when error correction is not performed.
2. Error correction protocol: Communication with error correction using Reed-Solomon code.
3. For error correction protocols, there are three types of protocol - 'without interleave' 'with interleave 1' and 'with interleave 2'.

* To set the communication protocol to the error correction protocol (error correction on), set to 'ON', 'I1' or 'I2' using the '@EC' command with the '/W' command option.
* The standard protocol is a protocol used when the error correction protocol is off.

◆ **The error correction protocol**
An error correction function with Reed-Solomon codes which corrects errors on the receiver side.
Reed-Solomon codes are effective in an environment where bust errors occur and reliable communication is required. In conventional communication systems, if an error occurs in the data sent between radios, the sent packet is discarded and a new packet must be sent, but by using error correction protocols for communication, the number of retries can be considerably reduced. However note that the communication speed with error correction is lower due to internal processing. Use the standard protocol if communication speed is important.

Effective radio communication speed (actual measurement value when transmitting 8,352 bytes)
1. **Standard protocol: 3,400 bps**
2. **Error correction protocol (without interleave): 2,300 bps**

Note *Basically communication is only possible between the same protocols

4.10 EEPROM readout error

When turning the power on, the MU-4 reads out the setting values previously written along with the internal parameter values from the EEPROM.
The setting values in the EEPROM can be rewritten with the command /W option, however, if the power is turned off during rewriting, the data will be corrupted.

If an error occurs when the MU-4 reads out the EEPROM data, an error response will be returned.

***ER=5x error**
This error means the corrupted data in the EEPROM was corrected by the internal error correction function.

***ER=4x error**
This error means the EEPROM contains multiple corrupted data which cannot be corrected by the internal error correction function.

For details of the error response, refer to the error code list.

EEPROM data blocks shown in the error response

The EEPROM data consists of 4 blocks from Block 0 to Block 3.

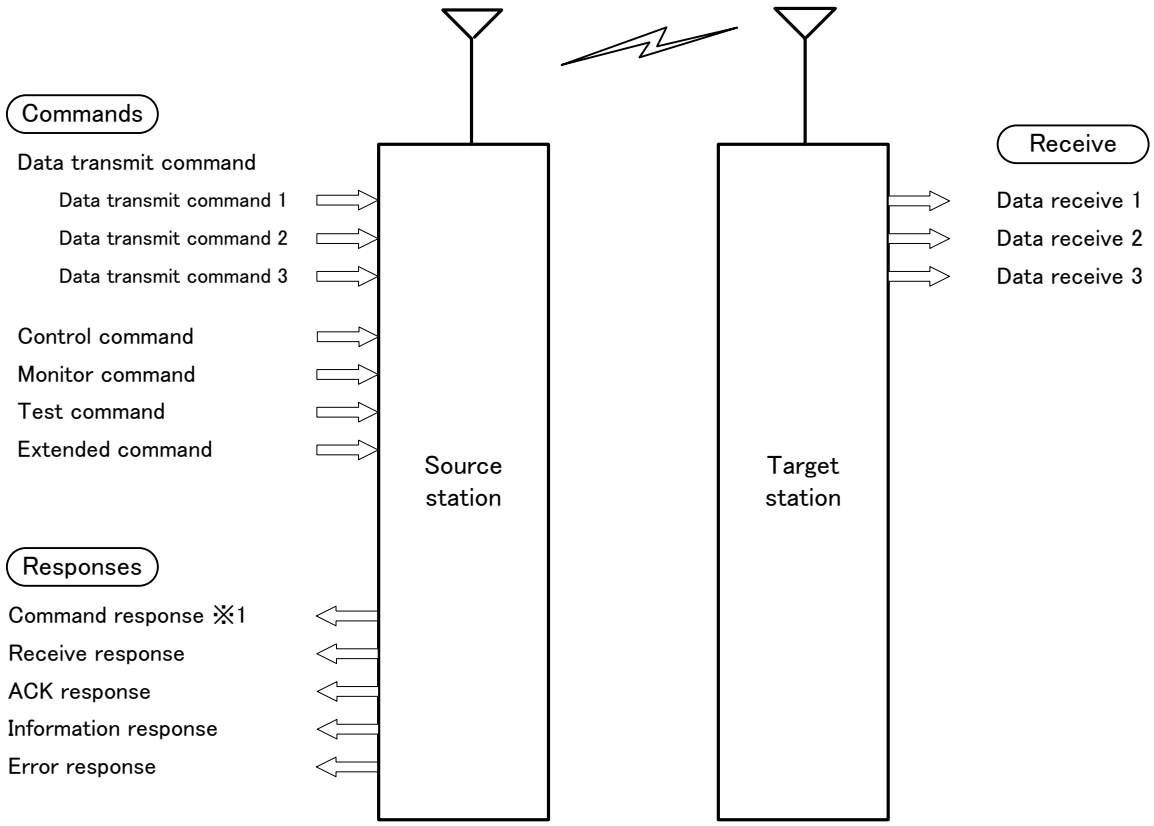
Block 0 and Block 2 are user data areas.
When an error of *ER = 5x occurs in these blocks, the data error has already been corrected by the error correction function. After confirming that the values of the restored data are correct, you can continue to use the MU-4 as it is.
If you get an error of *ER = 4x in these blocks, initialize the MU-4 and then set the values again.

Block 1 and Block 3 are the data areas for the system.
When an error of *ER = 5x occurs in these blocks, the system data error has been corrected by the error correction function. You can continue to use the MU-4 as it is.
If you get an error of *ER = 4x in these blocks, the system data area has been corrupted.
When a transmission-related command is issued in this state, an information response '*IR = 02: EEPROM System data error' is returned, and the MU-4 will not perform transmission operation.
The initialize function will also be disabled.
In this instance, it will be necessary to contact Circuit Design for a replacement.

Chapter 5 Commands, Responses and Receives

5.1 About the Command, Response and Receive

When the source station MU-4 receives a command from the user controller, it returns a command response to the user controller as an acknowledgment of command receipt. At the same time, it performs processing corresponding to the command. The commands, responses and receives the MU-4 uses are as follows.



※1 Command response types
・Data transmit response ・Control response ・Monitor response
・Test response ・Extended response

* The command response is a command receipt response corresponding to the issued command.

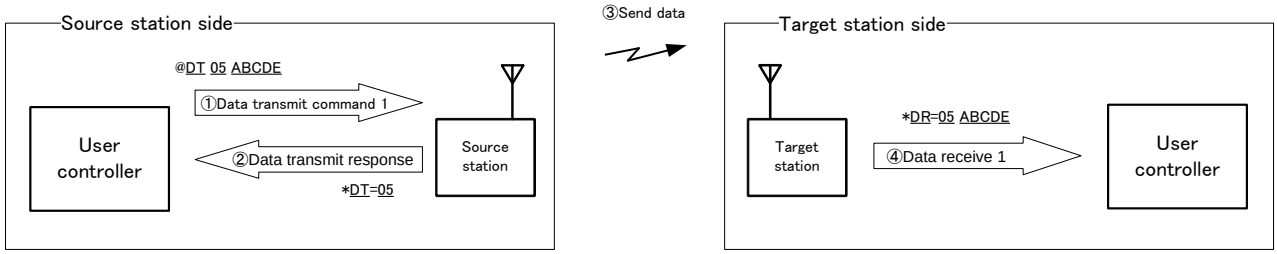
Command issued	Command responses
Data transmit command	→ Data transmit response
Control command	→ Control response
Monitor command	→ Monitor response
Test command	→ Test response
Extended command	→ Extended response

1. Data transmit command, data transmit response and data receive

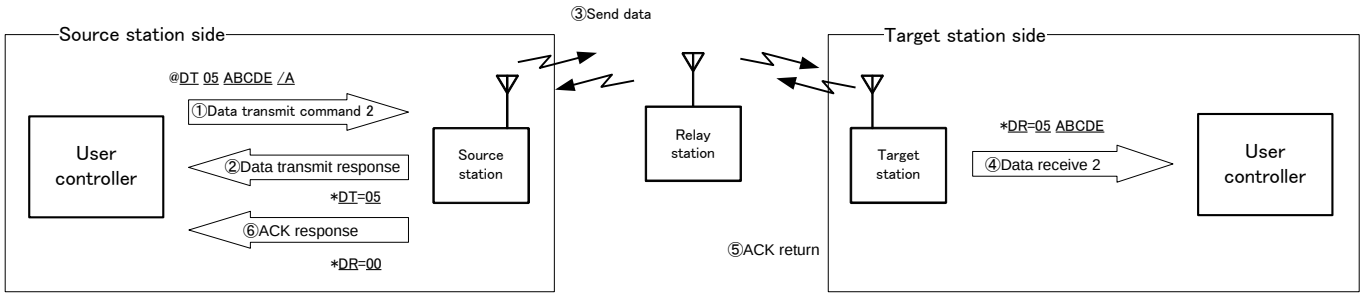
The data transmit commands are commands to transmit user data from the source station. The target station outputs a data receive corresponding to the data transmit command issued. There are three types of transmit command - data transmit command 1, data transmit command 2 and data transmit command 3.

Example 1 Data transmit command 1 (For 1:1 and 1:N systems)

It is also possible to receive an ACK response.

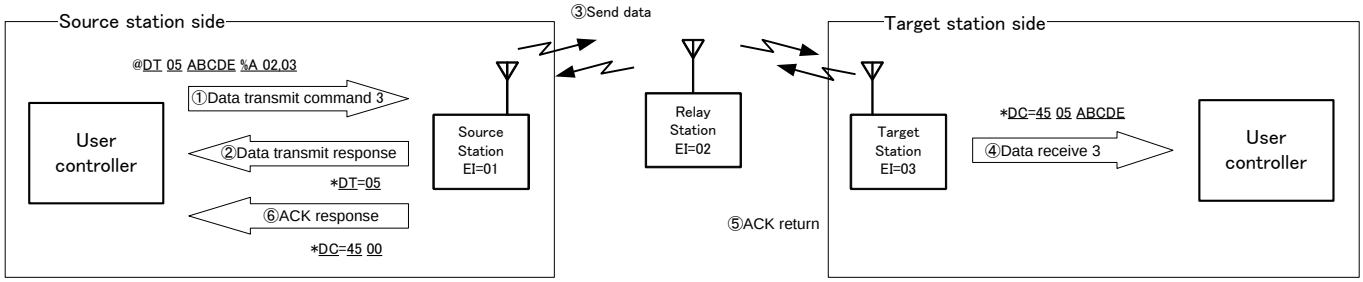


Example 2 Data transmit command 2 (Using the relay function, with ACK, route information specified in the route register)



Example 3 Data transmit command 3 (Using the relay function, with ACK, route information entered in command)

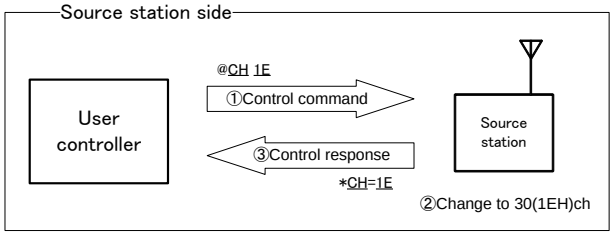
RSSI information is included at the front of the data receive. The RSSI level of the signal received at the target station is included at the front of the ACK response.



2. Control command and control response

Commands and responses for controlling the various operations of the MU-4.

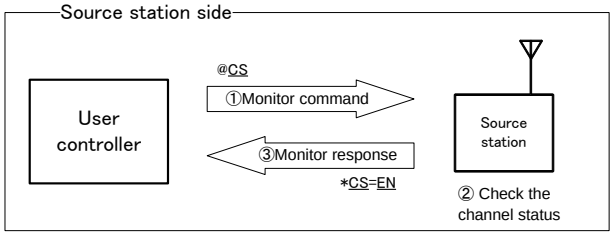
Example Change CH to 30(1Eh)



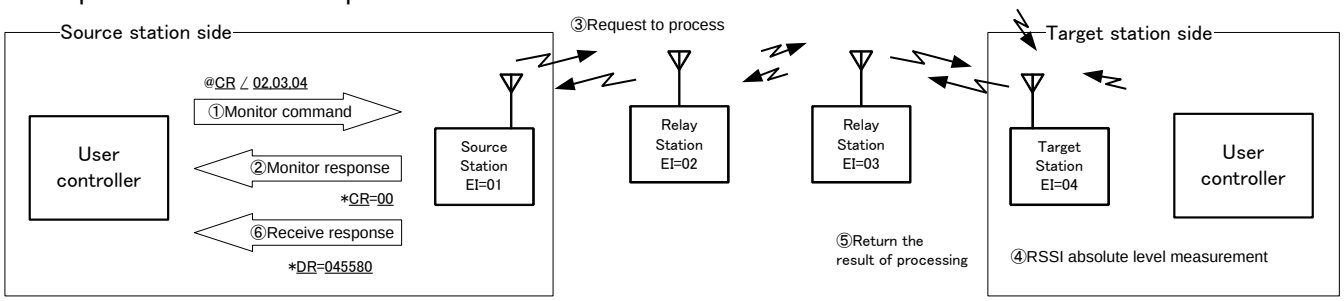
3. Monitor command and monitor response

Commands and responses for performing the various monitoring functions.

Example With no receive response

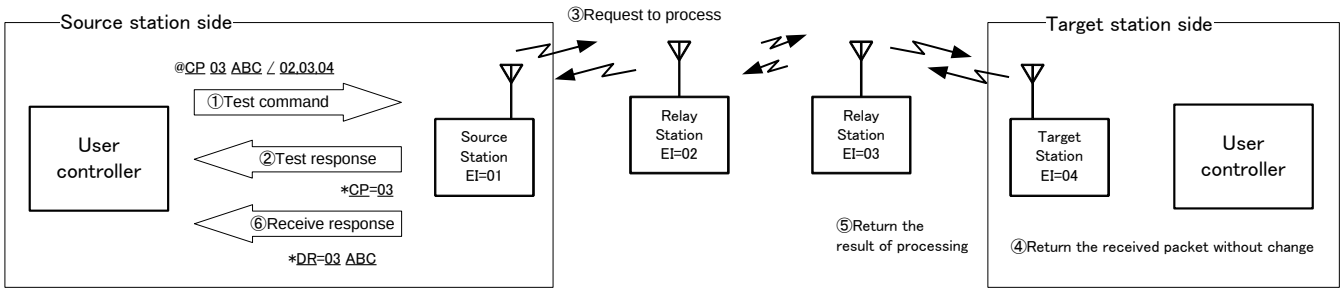


Example With receive response



4. Test command and test response

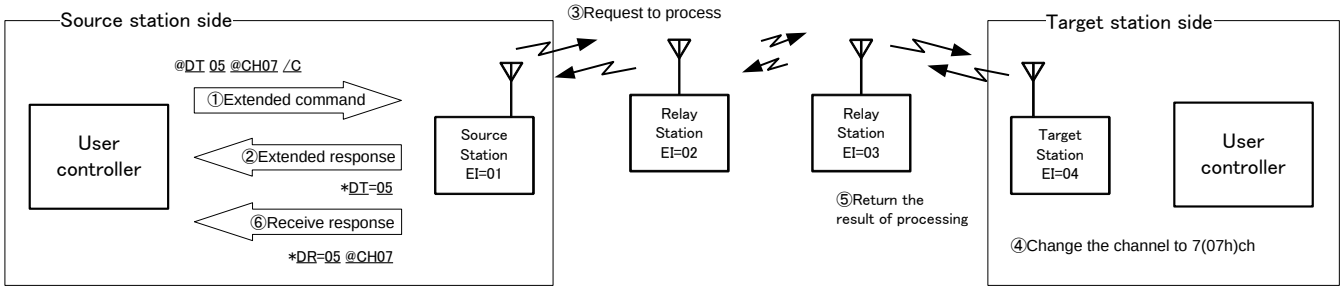
Commands and responses for performing the various test functions.



5. Extended command and extended response

Commands and responses for performing the extended functions.

Example Change the CH of the target station to 07



6. Receive response

When issuing the monitor command and extended command, processing is performed at the target station and the result is returned to the source station. This processing result is output from the source station as a receive response.

7. ACK response

When issuing the extended command and so on, an 'ACK' is returned to show that the target station received the command. This 'ACK' is output from the source station as an ACK response.

8. Information response

An information response returned from the MU-4 itself.

9. Error response

A response returned if there are errors in the format of the transmit command, control command and so on.

5.2 Command, Response and Receive Table

* In the table below, xx and XX, and XXXX are 2 and 4 digit hex values respectively. w indicates ASCII characters or byte data.

5.2.1 Data transmit commands and data transmit responses

Command name	Command format	Data transmit response format (Command response)	Page reference
Data transmit command 1 (no relay function)	**@DT XX ww...ww**	***DT = XX**	35
Data transmit command 2 (Relay function, no ACK)	**@DT XX ww...ww /R *1**	***DT = XX**	36
Data transmit command 2 (Relay function, ACK)	**@DT XX ww...ww /A *2**	***DT = XX**	36
Data transmit command 3 (Relay function, no ACK)	**@DT XX ww...ww %R *3**	***DT = XX**	39
Data transmit command 3 (Relay function, ACK)	**@DT XX ww...ww %A *4**	***DT = XX**	39

*1, 2: The options /S and /B output data at relay stations.
*3, 4: The options %S and %B output data at relay stations.

5.2.2 Data receives

A receiving data output from the target station.
Note that the data receive character string depends on the data transmit command issued from the source station.

Receive name	Receive format	Corresponding command	Page reference
Data receive 1	*DR = XX ww...ww *1	Data transmit command 1 (@DT)	35
Data receive 2	*DR = XX ww...ww *1	Data transmit command 2 (@DT..../)	36
Data receive 2 (With RSSI information)	*DS = xx XX ww...ww *2	Data transmit command 2 (@DT..../)	36
Data receive 3	*DC = xx XX ww...ww	Data transmit command 3 (@DT....%)	39

*1: When the mode setting with RF received signal level information SI is OF.
*2: When the mode setting with RF received signal level information SI is ON.

5.2.3 Control commands and control responses

Command type	Command name	Command format	Control response format (Command response)	Page reference
Radio link related setting and acquisition commands	User ID setting	@UI XXXX,XXXX	*UI = XXXX	48
	Group ID setting	@GI XX	*GI = XX	44
	Equipment ID setting	@EI XX	*EI = XX	44
	Destination ID setting	@DI XX	*DI = XX	43
	Relay route designation	@RT XX,XX,...,XX	*RT = XX,XX,...,XX	46
	Channel setting	@CH XX	*CH = XX	42
UART parameter setting commands	UART baud rate setting	@BR ww	*BR = ww	42
	UART parity setting	@PB ww	*PB = ww	44
	UART stop bit setting	@SB ww	*SB = ww	46
Operation setting and information acquisition commands	Operation mode setting	@MD ww	*MD = ww	44
	Command mode input waiting time setting	@TC XX	*TC = XX	47
	Time without input in the binary mode setting	@TB XX	*TB = XX	47
	Attach route information mode setting	@RI ww	*RI = ww	45
	Response display mode setting	@RM ww	*RM = ww	45
	Program version acquisition	@VR	*VR = XX ww...ww	48
	Serial number acquisition	@SN	*SN = wwwwwwwww	47
	Reset	@SR	*SR = 00	47
	Initialize	@IZ	*IZ = 00	44
	Mode setting with RF received signal level information	@SI ww	*SI = ww	46
	Receive route information use setting	@RR ww	*RR = ww	45
	Antenna power setting	@PW ww	*PW = ww	45
	Error correction protocol setting *1	@EC ww	*EC = ww	43

*1: The protocol used when the error correction protocol is off is defined as a standard protocol.

5.2.4 Monitor commands and monitor responses

Command name	Command format	Monitor response format (Command response)	Response type	Page reference
RSSI absolute level measurement	@RA	*RA = XX	No response	51
Target station all channel RSSI absolute level measurement	@CA	*CA = 00	Receive response	49
Target station RSSI absolute level measurement	@CR	*CR = 00	Receive response	50
All channel RSSI absolute level measurement	@RC	*RC = XX...XX	No response	51

*RSSI: Received Signal Strength Intensity

5.2.5 Test commands and test responses

Command name	Command format	Test response format (Command response)	Response type	Page reference
Test data continuous transmission	@CT ww	*CT = ww	No response	52
Packet test	@CP XX ww...ww	*CP = XX	Receive response	52

5.2.6 Extended commands and extended responses

Command function	Command format	Extend response format (Command response)	Response type	Page reference
Target station channel change Fixing the change in internal EEPROM	@DT 05 @CH XX /C @DT 07 @CH XX /W /C	*DT = 05 *DT = 07	ACK response	54
Multiple station channel change Fixing the change in internal EEPROM	@DT 05 @CH XX /F @DT 07 @CH XX /W /F	*DT = 05 *DT = 07	Control response	55
Target station test data issue	@DT 05 @CT XX /C	*DT = 05	ACK response	56
Target station reset	@DT 03 @SR /C	*DT = 03	ACK response	57
Resetting multiple stations at ones	@DT 03 @SR /F	*DT = 03	Control response	57

5.2.7 Receive response

When issuing the monitor command and extended command, processing is performed at the target station and the result is returned to the source station. This processing result is output from the source station as a receive response. The content of the receive response depends on the command issued. For details, refer to the explanation of the relevant command.

5.2.8 ACK response

When issuing the extended command and so on, an ‘ACK’ is returned to show that the target station received the command. The ‘ACK’ is output from the source station as an ACK response. The content of the ACK response depends on the command issued. For details, refer to the explanation of the relevant command.

5.2.9 Error response

A response returned if there are errors in the format of the transmit command, control command and so on.

5.3 Save Setting Command Options

By specifying the option '/W' as continuation of a command, command values can be fixed in the EEPROM within the MU-4. The next time the power is turned on, the contents of the EEPROM are set to the initial values. The time required for conversion is 65 ms.

The commands that can specify the option '/W' are as follows.

BR, CH, CT, DI, EC, EI, GI, MD, PB, PW, RI, RM, RR, RT, SB, SI, TC, TB, UI

Example: Fix the User ID as 0000h (UI=0000 is for testing)

Control command:	@UI 0000,0B27 /W CRLF
Control response:	*WR = PS CRLF
	*UI = 0000 CRLF

Example: Set the channel to ch 16 and fix it.

Control command:	@CH 10 /W CRLF
Control response:	*WR = PS CRLF
	*CH = 10 CRLF

Note

1. The command parameter is applied immediately after the command to change it is issued. In particular, note that if the UART related parameters are changed, communication will not be possible unless the UART parameters on the control side are also changed.
2. The maximum number of EEPROM conversions is 1,000,000. Do not design a program which needs to be rewritten repeatedly.
3. Do not issue other commands during conversion of the EEPROM.

5.4 Command, Response and Receive details

The default value In the explanation below, “Default” value is the factory setting set using the ‘INI’ terminal or by issuing the initialize command.

The terminator In the explanation below, the terminator, which is the characters that indicate the end of the command and response, is the symbol ‘CRLF’. ‘CRLF’: CR (carriage return: ‘CR’ = 0Dh) + LF (line feed: ‘LF’ = 0Ah)

5.4.1 Data transmit commands, responses and data receives

Data transmit command basic format

Prefix + command name + value + data + command option + terminator

Prefix: ‘@’=40h, a code that indicates the start of the command string.
Command name: The 2 ASCII characters ‘DT’. Specified with upper case or lower case characters.
Value: Specifies user data size with a hexadecimal number.
Data: Byte sequence of user data.
Command option: Specifies the operation of the command and route information.

◇ Data transmit command code (Transmission of 6-byte data)

Command string	Hexadecimal code actually sent to the MU-4
@DT 06 abc123 CRLF	**40,44,54,30,36,61,62,63,31,32,33,0D,0A**

Data transmission response basic format

Prefix + command name + ‘=’ + value + terminator

Prefix: ‘*’ = 2Ah, a code that indicates the start of the response string.
Command name: The ASCII characters ‘DT’.
Value: The size of data received with the ‘DT’ command

◇ Data transmit response code (255-byte data transmission)

Transmit response character string	Hexadecimal code actually issued from the MU-4
*DT = FF CRLF	**2A,44,54,3D,46,46,0D,0A**

Data receive basic format

Prefix + data receive name + ‘=’ + value 1 + value 2 + data + option data + terminator

Prefix: ‘*’ = 2Ah, a code that indicates the start of the response string.
Data receive name: The 2 ASCII characters ‘DR’,’DC’ or ‘DS’.
Value 1: 1 byte hexadecimal value to show the RSSI information. Specified by 2 ASCII characters.
Value 2: 1 byte hexadecimal value to show the size of the user data. Specified by 2 ASCII characters.
Data: Byte sequence of user data.
Option data: Route information and the like.

◇ Data receiver code

Data receive (receiving data) character string	Hexadecimal code actually returned from the MU-4
*DR = 06 abc123 CRLF	**2A,44,52,3D,30,36,61,62,63,31,32,33,0D,0A**

5.4.1.1 @DT Data transmit command 1

The data transmit command 1 '@DT' is a command used for systems that do not use the relay function. Data is transmitted towards the target station set as the Destination ID at the source station.

1. When the relay function is not used

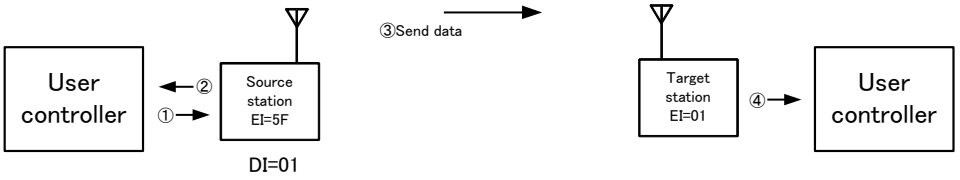
When the source station MU-4 receives the command from the user controller, it returns a command response as acknowledgment of receipt of the command. At the same time, it starts wireless data transmission. The target station MU-4 outputs the data receive 1 in the '*DR' format.

Format: '@' + 'DT' + data size + data + 'CRLF'

- Data size is specified by 2 hexadecimal ASCII characters. The maximum data size that can be sent at one time is 255 bytes.
- The data is a numerical value up to 00h to FFh.
- The data is sent to the target station set in the Destination ID: '@DI'

Format '@DT' ss DD....D 'CRLF'
ss: Shows the data size in 2 hexadecimal digits Value: 00h to FFh
DD...D: D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes

Example: Transmit the 10 bytes of data (0Ah) '0123ABC%#$' to the target station set in the Destination ID.
The target station Equipment ID = 01h. The source station Equipment ID = 5Fh.



・Source station 5F status

①Issue the data transmit command 1
@DT 0A 0123ABC%#$ CRLF

②Data transmit response
＊DT = 0A CRLF

③Send data

・Target station 01 status

④Data receive 1
When RI=OF ＊DR = 0A 0123ABC%#$ CRLF(Default)
When RI=ON ＊DR = 0A 0123ABC%#$ CRLF

◇ Data receive 1 (Target station output)

Example: Receives 5-byte user data (05h) 'ABCDE'

Source station = 01, relay stations = 02, when the received signal level is -69 dBm (45h)

Data transmit command 1: @DT 05 ABCDE CRLF
When SI is OF *DR = 05 ABCDE CRLF (default)
When SI is ON *DS = 45 05 ABCDE CRLF

*SI = Attach RSSI information mode

5.4.1.2 @DT.../ Data transmit command 2

Data transmit command 2 '@DT.../' is a command for the system using relay stations. Data transmit command 2 is provided to handle mainly user system data.

- The format of this command assumes the relay function, but can also be used for systems that do not use the relay function. With 1:1 communication, set only one Equipment ID for the target station at the end of the route information.
- If the attach RF received signal level mode setting command '@SI' is used, received signal level information for the packet is attached to the front of the data receive of the target station in response to data transmit command 2.
- There is also a method of notation where data transmit command 2 makes the target station return data receive acknowledgement 'ACK'.

1. Receive confirmation acknowledgement: no request for ACK

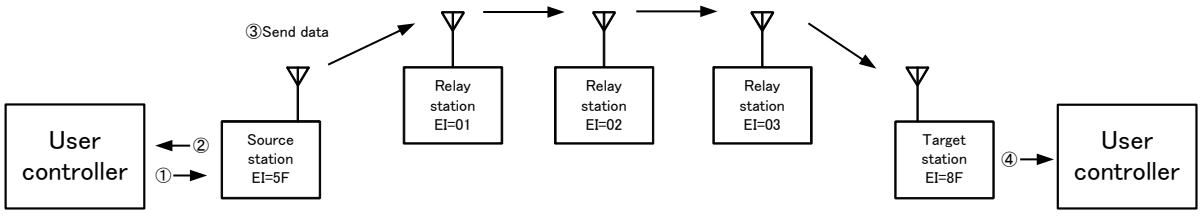
When the source station MU-4 receives data transmit command 2 '@DT.../R' from the user controller, it returns a command response as an acknowledgment of command receipt. At the same time, it starts wireless data transmission. The target station MU-4 outputs data receive 2 in the '*DR' format. This command does not request the target station to return a data receive acknowledgment 'ACK'.

Format 1: '@' + 'DT' + data size + data + '/R' + route information + 'CRLF'
Format 2: '@' + 'DT' + data size + data + '/R' + 'CRLF'

Details
Format '@DT' ss.DD....D '/R' rr,rr,...,rr 'CRLF'
ss: Shows the data size in 2 hexadecimal digits and ASCII characters. Value: 00h to FFh, maximum 255 bytes
DD...D: D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes
rr,rr,...,rr: Shows the route information in 2 hexadecimal digits and ASCII characters. Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- To output the same data from all currently connected relay stations, issue the command with '/S' instead of '/R'.

Example: Transmit the 10-byte (0Ah) data '0123ABC$#4' to target station ID = 8F via relay station IDs = 01, 02, 03. The source station Equipment ID = 5F.



・Source station 5F status

①Issue the data transmit command 2
Format 1:@DT 0A 0123ABC$#4 /R 01.02.03.8F CRLF
Format 2:@DT 0A 0123ABC$#4 /R CRLF

②Data transmit response
*DT=0A CRLF

③Send data

・Target station 8F status

④Data receive 2

When RI=OF *DR=0A 0123ABC$#4 CRLF(Default)

When RI=ON *DR=0A 0123ABC$#4 /R 5F.01.02.03 CRLF

* The relay stations output the same data as from the target station with '/S'.

◇ Data receive 2

Example: Receives 5-byte user data (05h) 'ABCDE'

Source station = 01, relay stations = 02, target station=03, when the received signal level is -69 dBm (45h)

Data transmit command 2 without ACK: @DT 05 ABCDE /R 02,03 CRLF

When RI=OFF (default)

When SI=OFF *DR = 05 ABCDE CRLF(default)

When SI= ON *DS = 45 05 ABCDE CRLF

When RI=ON

When SI=OFF *DR = 05 ABCDE /R 01,02 CRLF

When SI= ON *DS = 45 05 ABCDE /R 01,02 CRLF

* RI = Attach route information mode, SI = Attach RSSI information mode

2. Receive confirmation acknowledgement: with request for ACK

When the source station MU-4 receives the data transmit command 2 '@DT.../A' from the user controller, it returns a response as an acknowledgment of receipt of the command. At the same time, it starts wireless data transmission. The target station MU-4 outputs the data receive 2 in the '*DR' format. This command requests the target station to return a data receive acknowledgment 'ACK'.

Format 1: '@' + 'DT' + data size + data + '/A' + route information + 'CRLF'
Format 2: '@' + 'DT' + data size + data + '/A' + 'CRLF'

Details

Format '@DT' ss DD....D '/A' rr,rr,...,rr 'CRLF'

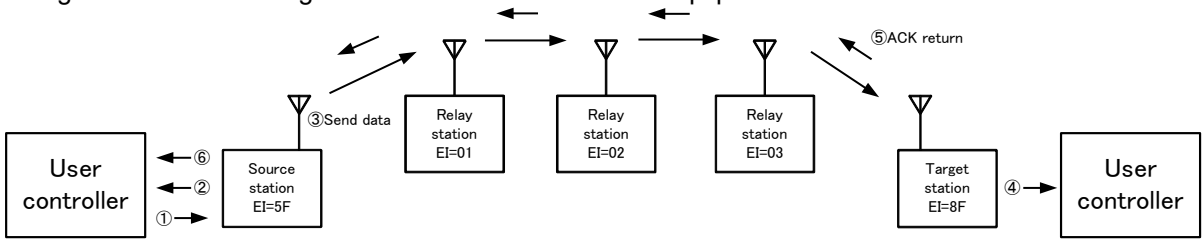
ss: Shows the data size in 2 hexadecimal digits and ASCII characters. Value: 00h to FFh, maximum 255 bytes

DD...D: D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes

rr,rr,...,rr: Shows the route information in 2 hexadecimal digits and ASCII characters. Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- To output the same data from all currently connected relay stations, issue the command with '/B' instead of '/A'.

Example: Transmit the 10-byte (0Ah) data '0123ABC%#4' to target station ID = 8F via relay station IDs = 01, 02, 03, and get ACK from the target station. The source station Equipment ID = 5F.



・Source station 5F status

①Issue the data transmit command 2

Format 1:@DT 0A 0123ABC$#4 /A 01,02,03,8F CRLF

Format 2:@DT 0A 0123ABC$#4 /A CRLF

②Data transmit response

*DT=0A CRLF

③Send data

⑥ACK response

*DR=00 CRLF (issued after the relay time has elapsed)

・Target station 8F status

④Data receive 2

When RI=OF ＊DR=0A 0123ABC$#4 CRLF(Default)

When RI=ON ＊DR=0A 0123ABC$#4 /R 5F,01,02,03 CRLF

⑤ACK return

The relay stations outputs the same data as from the target station with '/S'.

◇ Data receive 2 (Target station output)

Example: Receives 5-byte user data (05h) 'ABCDE'

Source station = 01, relay station = 02, target station=03, when the received signal level is -69 dBm (45h)

Data transmit command 2 with ACK: @DT 05 ABCDE /A 02,03 CRLF

When RI=OFF (default)
- When SI=OFF: *DR = 05 ABCDE CRLF(default)
- When SI= ON: *DS = 45 05 ABCDE CRLF

When RI=ON
- When SI=OFF: *DR = 05 ABCDE /A 01,02 CRLF
- When SI= ON: *DS = 45 05 ABCDE /A 01,02 CRLF

* RI = Attach route information mode, SI = Attach RSSI information mode

◇ ACK response (Source station output)

When the data transmit command 2 with ACK is issued from the source station, an ACK response is output from the source station. If the attach RF received signal level mode setting command '@SI' is set to ON, RSSI information for the ACK signal from the target station is attached to the ACK response. The ACK response is issued after the relay time has elapsed.

Example: The appearance of the source station ACK response when the 10-byte (0Ah) data 'PPPPPPPPPP' is transmitted with the data transmit command 2 with ACK.

Source station equipment ID = 01, relay station equipment ID = 02, target station equipment ID = 03

When the received signal level of the ACK signal is -102 dBm (66h)

1. When the mode setting with RF received signal level information SI is OF

Following the characters '*DR', '00' indicating the ACK response are output.

Issue data transmit command 2 with ACK @DT 0A PPPPPPPPPP /A 02,03 CRLF
- Source station output

*DT = 0A CRLF ← Data transmit response
*DR = 00 CRLF ← ACK response (issued after the relay time has elapsed)

- Target station output

*DR = 0A PPPPPPPPPP CRLF ← Data receive 2, RI=OF

2. When the mode setting with RF received signal level information SI is ON

Following the characters '*DS', the RSSI information and '00' indicating the ACK response are output.

Issue data transmit command 2 with ACK @DT 0A PPPPPPPPPP /A 02,03 CRLF
- Source station output

*DT = 0A CRLF ← Data transmit response
*DS = 66 00 CRLF ← ACK response (issued after the relay time has elapsed)

- Target station output

*DR = 0A PPPPPPPPPP /A 01,02 CRLF ← Data receive 2, RI=ON

5.4.1.3 @DT...% Data transmit command 3

The data transmit command 3 '@DT...%' is a command for systems using relay stations. When transmitting the user system data using data transmit command 2, it may be also required to perform various controls at the same time. In this case, using data transmit command 3 for control purposes makes it easy to design the program.

- The format of this command assumes the relay function, but it can also be used for systems that do not use the relay function. With 1:1 communication, set only one Equipment ID for the target station at the end of the route information.
- Received signal level information for the packet is always included at the front of the data receive of the target station in response to data transmit command 3.
- There is also a method of notation where data transmit command 3 makes the target station return data receive acknowledgement 'ACK'.

1. Receive confirmation acknowledgement: no request for ACK

When the source station MU-4 receives data transmit command 3 '@DT...%R' from the user controller, it returns a response as an acknowledgment of command receipt. At the same time, it starts wireless data transmission. The target station MU-4 outputs data receive 3 in the '*DC' format. This command does not request the target station to return a data receive acknowledgment 'ACK'.

Format 1: '@' + 'DT' + control size + control + '%R' + route information + 'CRLF'
Format 2: '@' + 'DT' + control size + control + '%R' + 'CRLF'

Details

Format '@DT' ss DD....D '%R' rr,rr,...,rr 'CRLF'

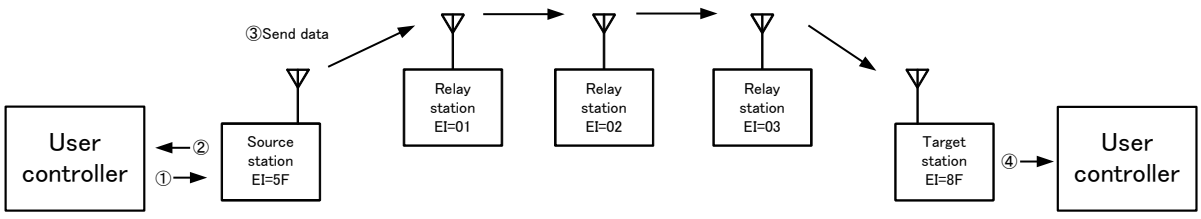
ss: Shows the control size in 2 hexadecimal digits and ASCII characters. Value: 00h to FFh, maximum 255 bytes

DD...D: D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes

rr,rr,...,rr: Shows the route information in 2 hexadecimal digits and ASCII characters. Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command. When entering the route information, enter the Equipment ID of the target unit at the end. With 1:1 communication, set only one Equipment ID for the target station in the route information. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- To output the same control from all currently connected relay stations, issue the command with '%S' instead of '%R'.

Example: Transmit the 10-byte (0Ah) control '0123ABC$#4' to target station ID = 8F via relay station IDs = 01, 02, 03. The source station Equipment ID = 5F.



・Source station 5F status

①Issue the data transmit command 3

Format 1:@DT 0A 0123ABC$#4 %R 01,02,03,8F CRLF

Format 2:@DT 0A 0123ABC$#4 %R CRLF

②Data transmit response

*DT=0A CRLF

③Send data

・Target station 8F status

④Data receive 3

When RI=OF *DC=45 0A 0123ABC$#4 CRLF(Default)

When RI=ON *DC=45 0A 0123ABC$#4 /R 5F,01,02,03 CRLF

* '45h' at the front indicates the signal level of the received packet. In this case, it is -69 dBm (45h). For details of the value, refer to the 'RA' command.
* When RI = ON, the delimiter character is '/', not '%'.

◇ Data receive 3

Example: Receives 5-byte user data (05h) 'ABCDE'

Source station = 01, relay station = 02, when the received signal level is -69 dBm (45h)

Data transmit command 3 without ACK: @DT 05 ABCDE %R 02,03 CRLF

When RI is OF *DC = 45 05 ABCDE CRLF (default)

When RI is ON *DC = 45 05 ABCDE /R 01,02 CRLF*1

*01= Note that the '%' for data transmit commands is '/' for data receives.

2. Receive confirmation acknowledgement: with ACK

When the source station MU-4 receives data transmit command 3 '@DT...%A' from the user controller, it returns a response as an acknowledgment of command receipt. At the same time, it starts wireless data transmission. The target station MU-4 outputs data receive 3 in the '*DC' format. This command requests that the target station return data receive acknowledgment 'ACK'.

Format 1: '@' + 'DT' + control size + control + '%A' + route information + 'CRLF'
Format 2: '@' + 'DT' + control size + control + '%A' + 'CRLF'

Details

Format '@DT' ss DD....D '%A' rr,rr,...,rr 'CRLF'

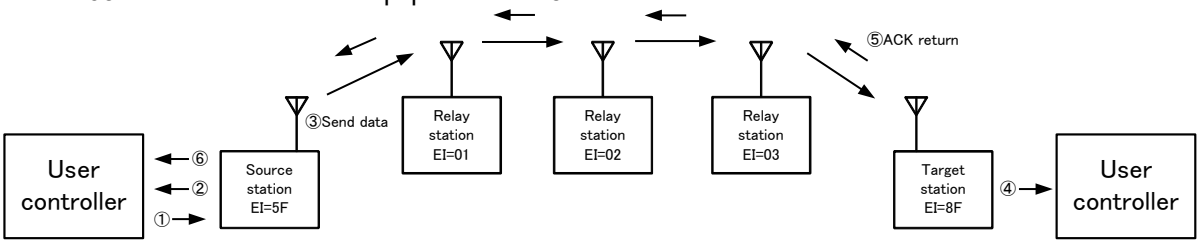
ss: Shows the control size in 2 hexadecimal digits and ASCII characters. Value: 00h to FFh, maximum 255 bytes

DD...D: D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes

rr,rr,...,rr: Shows the route information in 2 hexadecimal digits and ASCII characters. Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command. When entering the route information, enter the Equipment ID of the target unit at the end. With 1:1 communication, set only one Equipment ID for the target station in the route information. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- To output the same data from all currently connected relay stations, issue the command with '%B' instead of %/A'.

Example: Transmit the 10-byte (0Ah) control '0123ABC$#4' to target station ID = 8F via relay stations ID = 01, 02, 03. The source station Equipment ID = 5F.



・Source station 5F status

①Issue the data transmit command 3

Format 1:@DT 0A 0123ABC$#4 %A 01,02,03,8F CRLF

Format 2:@DT 0A 0123ABC$#4 %A CRLF

②Data transmit response

*DT=0A CRLF

③Send data

⑥ACK response

*DC=45 00 CRLF (issued after the relay time has elapsed)

・Target station 8F status

④Data receive 3

When RI=OF ＊DC=45 0A 0123ABC$#4 CRLF(Default)

When RI=ON ＊DC=45 0A 0123ABC$#4 /R 5F,01,02,03 CRLF

⑤ACK return

* '45h' at the front indicates the signal level of the received packet. In this case, it is -69 dBm (45h). For details of the value, refer to the 'RA' command.
* When RI = ON, the delimiter character is '/', not '%'.

◇ Data receive 3 (Target station output)

Example: Receives 5-byte user data (05h) 'ABCDE'
Source station = 01, relay station = 02, when the received signal level is -69 dBm (45h)

Data transmit command 3 with ACK:	@DT 05 ABCDE %A 02,03 CRLF
When RI is OF	*DC = 45 05 ABCDE CRLF (default)
When RI is ON	*DC = 45 05 ABCDE /A 01,02 CRLF *1

*01= Note that the '%' for data transmit commands is '/' for data receives.

◇ ACK response (Source station output)

When data transmit command 3 with ACK is issued from the source station, an ACK response is output from the source station. Regardless of the mode set with the attach RF received signal level mode setting command '@SI', RSSI information for the received signal at the target station is attached to the ACK response. The ACK response is issued after the relay time has elapsed.

Example: The appearance of the source station ACK response when the 10-byte (0AH) data 'PPPPPPPPPP' is transmitted with control transmit command 3 with ACK.

Following the characters 'DC', the RSSI information and '00' indicating the ACK response are output.

Source station equipment ID = 01, relay station equipment IDs = 02, 03, target station equipment ID = 04
When the received signal level of the target station is -85 dBm (55h)

Issue Data transmit command 3 with ACK	@DT 0A PPPPPPPPPP %A 02,03,04 CRLF
• Source station output	
*DT = 0A CRLF	← Data transmit response
*DC = 55 00 CRLF	← ACK response (issued after the relay time has elapsed)
• Target station output	
*DC = 55 0A PPPPPPPPPP CRLF (default)	← Data receive 3, RI=OF
*DC = 55 0A PPPPPPPPPP /A 01,02,03 CRLF	← Data receive 3, RI=ON

5.4.2 Control commands and control responses

Command basic format

Prefix + command name + value + terminator

Prefix: '@'=40h, a code that indicates the start of the command string.
Command name: 2 ASCII characters. Specified with upper case or lower case characters.
Value: Value corresponding to the relevant command.
Terminator: A code that indicates the end of the command 'CRLF' (0Dh, 0Ah).

◇ Control command code

Command string	Hexadecimal code actually sent to the MU-4
@ CH 1FCRLF	**40,43,48,31,46,0D,0A**

Response basic format

Prefix + command name + '=' + value + terminator

Prefix: '*' = 2Ah, a code that indicates the start of the response string.
Command name: 2 ASCII characters for the received command.
Value: Result value corresponding to the relevant command.
Terminator: A code that indicates the end of the command 'CRLF' (0Dh, 0Ah).

◇ Command response code

Response character string	Hexadecimal code actually returned from the MU-4
* CH = 1F CRLF	**2A,43,48,3D,31,46,0D,0A**

Note

The command parameter is applied immediately after the command to change it is issued. In particular, note that if the UART related parameters are changed, communication will not be possible unless the UART parameters on the control side are also changed.

5.4.2.1 @BR UART baud rate setting

Sets the UART baud rate. The change of setting is applied immediately after the response to the command is returned. Change the baud rate on the control side immediately.

Default: 19
Value: 12 = 1,200 bps 24 = 2,400 bps 48 = 4,800 bps 96 = 9,600 bps
19 = 19,200 bps 38 = 38,400 bps 57 = 57,600 bps
Example: Change to 57,600 bps
Control command: @BR57 CRLF Control response: * BR = 57 CRLF

5.4.2.2 @CH Frequency channel setting

Sets the channel to be used. Specify the channel following '@CH' with 2 ASCII (hexadecimal) characters.

Default: 01h
Value: 01h - 7Fh (hexadecimal value that indicates channels 1 to 127)

Example: Change the channel to 15 (0Fh)
Control command: @CH0F CRLF

Control response:
When RM = CD * CH = 0F CRLF
When RM = TX * CH =0F : 433.3750MHz CRLF

5.4.2.3 @DI Destination ID setting

Sets the destination (target station). Refer also to the explanation of User ID and Group ID.
If 00 is specified as the Destination ID, all equipment within the same group will receive the data at the same time (broadcast function). If FFh is set, the data is sent but no station will receive it.
The broadcast function cannot be used when using the relay function.

Default: 01h
Value: 00h to FFh (00h and FFh are special operations)

Example: Change the Destination ID to 25h
Control command: @DI25 CRLF Control response: *DI = 25 CRLF

5.2.2.4 @EC Error correction protocol setting

Specifies whether or not to set the communication protocol to the error correction protocol.
In order to set to the error correction protocol, set to ON, I1 or I2. This command requires the command option '/W'.
If the '@EC' command is issued, the internal settings of the MU-4 are reset to the status when the power was turned on. A communication protocol used when the error correction protocol is off is defined as the standard protocol.

Default: OF Error correction protocol OFF (= standard protocol)
Value: OF = Error correction protocol OFF (= standard protocol)
ON = Error correction protocol without interleave
I1 = Error correction protocol with interleave 1
I2 = Error correction protocol with interleave 2

Example 1 Set to the error correction protocol
Control command: @EC ON /W CRLF
Control response: *WR = PS CRLF *EC = ON CRLF

Example 2 Terminate the error correction protocol (set to the standard protocol)
Control command: @EC OF /W CRLF
Control response: *WR = PS CRLF *EC = OF CRLF

Communication availability

Communication protocol for transmission			Communication protocol for receiving (○:Communication can be established)			
	Data size	Applicable command	Standard protocol @EC OF/W	Error correction protocol Without interleave @EC ON/W	Error correction protocol Interleave 1 @EC I1/W	Error correction protocol Interleave 2 @EC I2/W
Standard protocol @EC OF/W	0～255	All	○	×	×	×
Error correction protocol Without interleave @EC ON/W	0～255	All	×	○	○	○
Error correction protocol Interleave 1 @EC I1/W	0～8	@DT @CP	×	×	○	×
Error correction protocol Interleave 2 @EC I2/W	0～32	@DT @CP	×	×	×	○

5.4.2.5 @EI Equipment ID setting

Sets the Equipment ID. One group can contain 254 units. Refer also to the explanation of User ID and Group ID.
The Equipment ID 00h is used for the broadcast function, and there is no reason for setting it.
If the Equipment ID FFh is specified, data will not be received. In this case, if the '@RA' command is used, only RSSI level data is output.

Default: 01h
Value: 01h to FFh (FFh is a special operation)

Example: Change the Equipment ID to 34h

Control command: @EI 34 CRLF Control response: *EI = 34 CRLF

5.4.2.6 @GI Group ID setting

Sets the Group ID. Refer also to the explanation of the User ID.
There are 256 Group IDs. Maintain these IDs for use as identification numbers when building other user systems.

Default: 00h
Value: 00h – FFh

Example: Change the Group ID to 34h

Control command: @GI 34 CRLF Control response: *GI = 34 CRLF

5.4.2.7 @IZ Initialize

Returns the MU-4 to the factory default values. The content of the EEPROM fixed with the '/W' option is also initialized. For default values, refer to the relevant command.
After using this command, always execute the SR command.

Example:
Control command: @IZ CRLF
Control response from the MU-4:
When RM = CD *IZ = 00 CRLF
When RM = TX *IZ = 00 : ROM was initialized. CRLF

5.4.2.8 @MD Operation mode register setting

Sets the MU-4 operation mode register. The mode is determined in accordance with the status of the MODE terminal. For details, refer to the item "Modes". No commands can be used except in the command mode (CD).

Default: CD
Value: CD: Command mode TX: Text mode BI: Binary mode

Example 1: Change to the text mode
Control command: @MD TX CRLF Control response: *MD = TX CRLF
Example 2: Change to the binary mode
Control command: @MD BI CRLF Control response: *MD = BI CRLF

5.4.2.9 @PB UART parity bit setting

Sets the UART parity bit of the MU-4. The change of setting is applied immediately after the response to the command is returned. Change the parity on the control side immediately.

Default: NO
Value: NO = None EV = Even OD = Odd

Example: Change to even parity
Control command: @PB EV CRLF Control response: *PB = EV CRLF

5.4.2.10 @PW Antenna power setting

Lowers the antenna power of the MU-4 from the standard 10 mW to 1 mW.

Default: 10 (10 mW)
Value: 01 = 1 mW 10 = 10 mW

Example Set to 1 mW
Control command: @PW 01 CRLF Control response: *PW = 01 CRLF

5.4.2.11 @RI Attach route information mode

Specifies whether or not to include route information in the data receive ('*DR') at the target station.
To include route information, set to ON.

Default: OF
Value: ON: Attach route information OF: No route information

Example 1: Attach route information mode setting
Control command: @RI ON CRLF Control response: *RI = ON CRLF

Example 2: DR response
When RI is ON *DR = 03 ABC /R 20,01,02,03 CRLF
When RI is OF *DR = 03 ABC CRLF

5.4.2.12 @RM Response display mode

Sets the method of displaying the content of responses to either code or text.
Text display is the mode for connecting to a PC with an RS232C conversion board in order to check the content of responses.
Normally the code display mode should be used.

Default: CD
Value: CD: Code display mode TX: Code and text display mode

Example: Change the response display method to code display
Control command: @ RM CD CRLF Control response: *RM = CD CRLF

5.4.2.13 @RR Receive route information use setting

Writes the route information of the received data packet in the route register, and sets whether or not to use it as return route information. If a data transmit command (control transmit command) transmitted in accordance with the content of the route register is issued at the target station, the data is sent automatically towards the source station. However, note that the route information set with the route setting command is overwritten each time a data packet is received. This operation is only enabled when a transmit command is received from the source station.

Default: OF
Value: ON: Receive route information used OF: Receive route information setting not used

Example: Turn on use of receive route information
Control command: @RR ON CRLF Control response: *RR = ON CRLF

5.4.2.14 @RT Relay route designation

Sets the route information in the route register. Setting is possible up to a maximum of 10 relay stations. When entering the route information, enter the Equipment IDs (EI) of the relay stations in the order of the relay. Specify the Equipment ID (EI) of the target station at the end. For details of data transmission using relay stations, refer to the DT command.

Default: NA The response corresponding to the @RT command is *RT = NA
Value: NA or (00h – FEh),.....,(00h-FE) A maximum number of 10 units can be specified
However, 00h is for broadcast communication, while setting NA disables the route information in the route register and enables the ID set with the @DI command.

Example: Set route information for transmitting 'ABC' from the source station with Equipment ID = 5F via relay station IDs 01, 02 and 03 to target station Equipment ID = 8F.

Control command: @RT 01,02,03,8F CRLF
Control response: *RT = 01,02,03,8F CRLF

Hint: When only one Equipment ID is entered in the RT command, that becomes the direct target station.

5.4.2.15 @SB UART stop bit setting

Sets the UART stop bit of the MU-4. The change of setting is applied immediately after the response to the command is returned. Change the stop bit on the control side immediately.

Default: 01
Value: 01 = Stop bit 1 02 = Stop bit 2

Example: Change to Stop bit 1
Control command: @SB 01 CRLF Control response: *SB = 01 CRLF

5.4.2.16 @SI Mode setting with RF received signal level information

Sets whether or not to include the RF received signal level information (RSSI) of the received packet data in the data receive at the source station or the ACK response and receive response at the source station. To include the information, set the mode to ON. The information is attached to the front of the data receive ('*DS'). With OF, the data receive is '*DR'. This mode is applied to all commands which involve a receiving operation at the source station or target station. However with data transmit command 3, RSSI information is always added to the data receive character string or AKC response character string.

Default: OF
Value ON: Attach RSSI information OF: No RSSI information

Example 1: Attach RSSI information mode setting
Control command: @SI ON CRLF Control response: *SI = ON CRLF

Example 2: Appearance of the target station data receive and source station ACK response

Target station data receive
when the RSSI of the received packet data is -85 dBm = 55 hex
• When the data transmit command 2 is issued from the source station
When SI = ON, RI = OF *DS = 55 03 ABC CRLF
When SI = ON, RI = ON *DS = 55 03 ABC /R 20,01,02,03 CRLF
When SI = OF, RI = OF *DR = 03 ABC CRLF
When SI = OF, RI = ON *DR = 03 ABC /R 20,01,02,03 CRLF

Source station ACK response

when the RSSI of the ACK response received from the target station is -70 dBm=46 hex
• When the data transmit command 2 is issued from the source station
When SI = OF *DR = 00 CRLF
When SI = ON *DS = 46 00 CRLF

5.4.2.17 @SN Show serial number

Shows the serial number of the MU-4. The serial number is the 9-digit control number shown on the label of the main unit. The response from the MU-4 is in ASCII characters.

Example:
Control command: @SN CrLf
Control response: *SN = A12345678 CrLf

5.4.2.18 @SR Reset

Returns the MU-4 to the status when the power is turned on. The MU-4 starts up with the fixed content of the EEPROM with the '/W' option. The command response for the 'SR' command is issued immediately after the command is received. The time during which commands cannot to be received is 120 ms when the '@SR' command is issued and 100 ms when the hardware is reset at the INI terminal.

Example:
Control command: @SR CrLf
Control response:
When RM = CD *SR = 00 CrLf
(When RM = TX *SR = 00 : Software reset was performed. CrLf)

5.4.2.19 @TB Time without input in the binary mode setting

In the binary mode, if the status where no UART data is input continues beyond the set time, transmission of data in the buffer starts automatically.
Calculate the setting value with 32 ms per 1 count.

Default: 10h (16 × 32 = 0.512 s)
Value: 01h to FFh: 1 count = 32 ms

Example: Set the time to 20h (1.02 s)
Control command: @TB 20 CrLf Control response: *TB = 20 CrLf

5.4.2.20 @TC Command mode input waiting time

If command input is not completed within the time set, the character string input so far is cleared and the unit returns to the input standby status.
Calculate the setting value with 0.512 s per 1 count.

Default: 00h (No limit for input time)
Value: 00h - 7Fh

Example: Set waiting time to 0Ah (10 × 0.512 = 5.12 s)
Control command: @TC 0A CrLf Control response: *TC = 0A CrLf

* This command is provided to support for RS232C communication software on a PC for sending character data with key input.

5.4.2.21 @UI User ID setting

User IDs are IDs (about 30,000) that are meant to prevent data interference with other systems within a given area, and if all the equipment within the same user system does not have the same ID, communication cannot be established. The link parameters derive from the Group ID, Equipment ID, and Destination ID.
All MU-4 units have a default User ID of 0000h, and they can be used with this value, but to avoid data collision with other users in the same area, we recommend that you set a User ID other than 0000h for actual operations with the MU-4.
If a unique User ID is required, we will provide it along with a password. Please contact Circuit Design, Inc directly. Please ensure that you do not lose your User ID and password (we also maintain records of this information).

*About 30,000 User IDs are ensured, but there may be duplicates if the IDs should be required in excess of this range. In other words, the User ID does not guarantee the security of data. However since it is not likely that more than 30,000 User IDs are issued and there is also a very small possibility of overlapping in the same area, you can use it at ease.

A password is required for setting a User ID, but the passwords for the following 16 User IDs are publicly available so they can be used freely. The password follows the User ID in brackets.

0000 (0B27), **EFF1** (4E74), **EFF2** (D18E), **EFF3** (5909), **EFF4** (82B5),
EFF5 (9D47), **EFF6** (E4D1), **EFF7** (3B2F), **EFF8** (B3A6), **EFF9** (6C5A),
EFFA (C6F7), **EFFB** (7F6F), **EFFC** (15C4), **EFFD** (0A34), **EFFE** (F7E8), **EFFF** (A09C)

Default: 0000h
Value: 01h to FFh (0000h is for testing, FFh cannot be used)

Example: Set the User ID to 0000h with the password 0B27h provided.

Control command: @UI 0000,0B27 CRLF Control response: *UI = 0000 CRLF

* For ordinary applications, fix the UI, GI, and EI in the EEPROM with the command /W option.
* Please contact the distributor or Circuit Design, Inc. if you require multiple User IDs.

5.4.2.22 @VR Display program version

Obtains the program version of the MU-4.

Example:
Control command: @VR CRLF
Control response: *VR = 12 Ver1.2A 2007/01/11 11:02 CRLF

5.4.3 Monitor commands and Responses

5.4.3.1 @CA Target station all channel RSSI absolute level measurement

The RSSI (Received Signal Strength Intensity) of the specified target station is measured over all channels. It is possible to check the floor noise level of the field, third party field strength, and noise level of the system itself. The RSSI value is the received strength of the radio waves inducted through the antenna of the target station. The measured value is output as a 2-digit hexadecimal number in ASCII characters that expresses the absolute value for RSSI. The code of the RSSI value acquired is minus.

Format 1: '@' + 'CA' + '/' + route information + 'CRLF'
Format 2: '@' + 'CA' + 'CRLF'

Details
Format1: '@CA' '/' rr,rr,...,rr 'CRLF'
Format2: '@CA' '/' 'CRLF'
rr,rr,…,rr: Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- It is possible to make the source station the target. In this case, after entering one or more relay stations, enter the Equipment ID of the source station at the end.

Example: The RSSI of target equipment number 8F is measured over all channels. The relay stations are 01, 02, and 03.

- Source station status
  Test command: @CA / 01,02,03,8F CRLF or @CA CRLF
  Test response: *CA = 00 CRLF
  Receive response with regard to the data transmitted from the target station:
  *DR = FE 7C7D....7E7D CRLF
  A response for 127 channels of RSSI is returned as 254-byte (FE hex) ASCII characters (code is minus)

- Target station status
  There is no response.

5.4.3.2 @CR Target station RSSI absolute level measurement

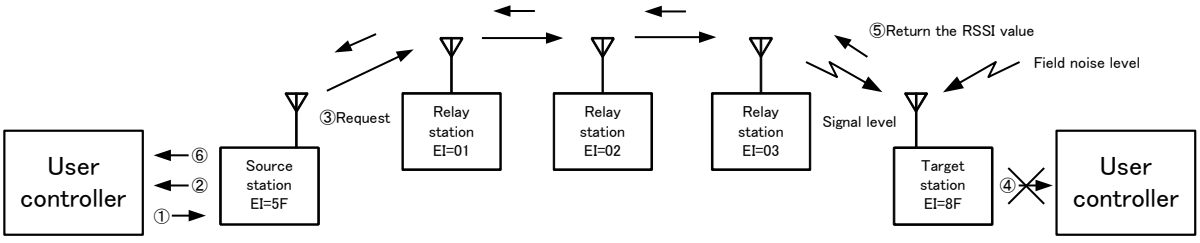
Measures the RSSI (Received Signal Strength Intensity) of the specified target station. The RSSI value is the received signal strength of the target station. In addition, the floor noise level of the field where the target station is located can also be acquired. The measured value is output as a 2-digit hexadecimal number in ASCII characters that expresses the absolute value for RSSI. The code of the RSSI value acquired is minus.

Format 1: '@' + 'CR' + '/' + route information + CRLF
Format 2: '@' + 'CR' + CRLF

Details
Format1: '@CR' '/' rr,rr,...,rr 'CRLF'
Format2: '@CR' '/' 'CRLF'
rr,rr,...,rr: Shows the route information in 2 hexadecimal digits and ASCII characters. Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- It is possible to make the source unit the target. In this case, after entering one or more relay stations, enter the Equipment ID of the source unit at the end.

Example: Measure the RSSI of target equipment number 8F. The relay stations are 01, 02, and 03.



・Source station 5F status

①Issue the monitor command
Format 1:@CR / 01,02,03,8F CRLF
Format 2:@CR CRLF

②Monitor response:*CR=00 CRLF

③Request

⑥Receive response from the target station (issued after the relay time has elapsed)
When RM=CD *DR=04 5580 CRLF
When RM=TX *DR=14 CRLF S −85dBm N −128dBm CRLF

・Target station 8F status

④There is no data receive

⑤Return the RSSI value of the current channel
Measure and return the packet signal level and field noise.

◇ Receive response (Source station output)

The signal level and filed noise level of the target station are output as the receive response. The measured value is output following the data size as a 2-digit hexadecimal number that expresses the absolute value for RSSI. The RSSI value for one channel is expressed as 2-byte ASCII characters and the code of the RSSI value acquired is minus.

- Source station output
- *DR = 04 55 80 CRLF

* Hex '55'= -85 dBm, Hex '80'= -128 dBm, '55'=35,35 (ASCII code)

5.4.3.3 @RA RSSI absolute value measurement

Measures the absolute value for Received Signal Strength Intensity (RSSI) of the channel set. The measured value is a hexadecimal value that indicates the RSSI absolute value.
The code of the RSSI value acquired is minus.

Format 1: '@' + 'RA' + 'CRLF'

Details
Format: '@RA CRLF'

Range of the hexadecimal value that indicates the RSSI absolute value: 00h to FFh

Example: Measure the RSSI absolute value of the current channel
Monitor command: @RA CRLF
Monitor response:
When RM = CD *RA CRLF *63h = 99
(When RM = TX *RA = 63 -99dBm CRLF)

5.4.3.4 @RC All channel RSSI absolute level measurement

Measures the RSSI (Received Signal Strength Intensity) over all channels. It is possible to check the floor noise level of the field, third party field level, and field level of the system itself. The measured value is output as a 2-digit hexadecimal number in ASCII characters that expresses the absolute value for RSSI. The code of the RSSI value acquired is minus.

Format 1: '@' + 'RC' + 'CRLF'

Example: Measure the RSSI absolute value over all channels.
Monitor command: @RC
Monitor response: *RC = 7A7C7D....7E7D CRLF
A response is returned for 127 channels of RSSI data (254-byte ASCII characters)
The code is minus. 7A = -122dBm

5.4.4 Test commands and Responses

5.4.4.1 @CT Test data transmission

Transmits test data from the source station for the time specified. Specify 'ON' to transmit data continuously, specify a count value when transmitting for a specified time, and specify 'OF' to stop transmission. The transmission data is 'CRLF' sent repeatedly, and the receive response of the target station is '*DR = 00'. If there is any input data during transmission, the data is transmitted.

Default: 'OF'
Value: 'ON': Continuous transmission (on), 'OF': Continuous transmission (off), Count value: ASCII code that expresses 01h to FFh

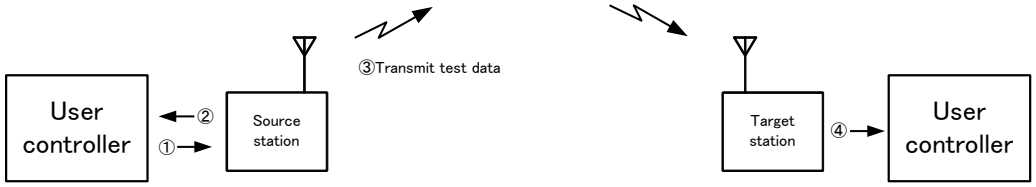
The count value is 10 seconds per count. The maximum value is FFh, 2,550 seconds.

Example 1: Continuous data transmission on

Test command: @CT ON CRLF Test response: *CT = ON CRLF

Example 2: Continuous data transmission off
Test command: @CT OF CRLF Test response: *CT = OF CRLF

Example 3: Transmit data for 60 seconds
Test command: @CT 06 CRLF Test response: *CT = ON CRLF



・Source station 5F status
①Issue the test command @CT 06 CRLF
②Test response:*CT=ON CRLF
③Transmit test data

・Status of all target stations
④Data receive *DR=00
・If the Destination ID matches, data receive is output for specified time.
・To measure the RSSI of the test signal, set the target station Equipment ID to 'FFh' and use the '@RA' command.

5.4.4.2 @CP Packet test

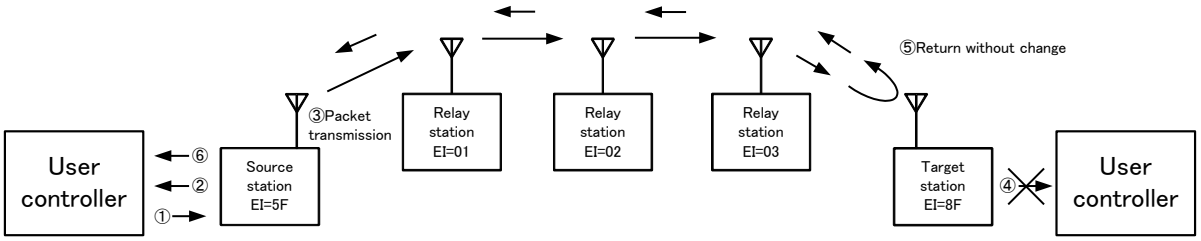
Transmits data for packet testing.
Transmits data packets to the specified target unit, and the target unit returns the data without change. Any packet length from 1 to 255 bytes can be specified.

Format 1: '@' + 'CP' + data size + data + '/' + route information + 'CRLF'
Format 2: '@' + 'CP' + data size + data + 'CRLF'

Details
Format1: '@CP' ss DD....D '/A' rr,rr,...,rr 'CRLF'
Format2: '@CP' ss DD....D '/A' 'CRLF'
ss: Shows the data size in 2 hexadecimal digits and ASCII characters. Value: 00h to FFh, maximum 255 bytes
DD...D: D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes
rr,rr,...,rr: Shows the route information in 2 hexadecimal digits and ASCII characters. Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.

Example: Transmit 'ABC' from the source station with Equipment ID = 5F via relay station IDs 01, 02 and 03 to target station Equipment ID = 8F, and the data is returned without change.



・Source station 5F status

①Issue the test command
Format 1:@CP 03 ABC / 01,02,03,8F CRLF
Format 2:@CP 03 ABC CRLF

②Test response:*CP=00 CRLF

③Transmit data packet

⑥Receive response from the target station
*DR=03 ABC CRLF (issued after the relay time has elapsed)

・Target station 8F status

④There is no data receive

⑤Return the data packet without change

◇ Receive response (Source station output)

The packet data sent to the target station is returned without change and output as the receive response.

• Source station output
*DR = 03 ABC CRLF

5.4.5 Extended command and extended response

5.4.5.1 '@DTxx@CHxx/C' Change the target station channel

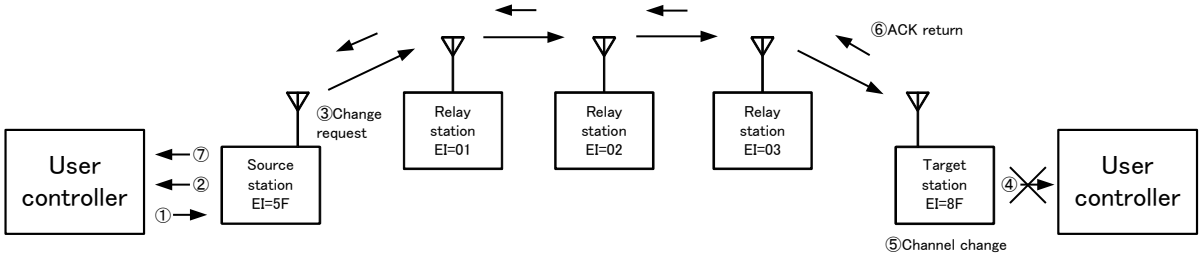
Changes the channel used by the specified target station. Start changing the channels of the equipment located furthest away.

Format 1: '@' + 'DT05' + '@CH' + channel number + '/C' + route information + 'CRLF'
Format 2: '@' + 'DT05' + '@CH' + channel number + '/C' + 'CRLF'
Format 3: '@' + 'DT07' + '@CH' + channel number + '/W' + '/C' + route information + 'CRLF'
Format 4: '@' + 'DT07' + '@CH' + channel number + '/W' + '/C' + 'CRLF'

Details
Format 1: '@DT05' '@CH' cc '/C' rr,rr,...,rr 'CRLF'
Format 2: '@DT05' '@CH' cc '/C' 'CRLF'
Format 3: '@DT07' '@CH' cc '/W' '/C' rr,rr,...,rr 'CRLF'
Format 4: '@DT07' '@CH' cc '/W' '/C' 'CRLF'
cc: Enter the channel number in 2 hexadecimal digits and ASCII characters Value: 01h to 7Fh
rr,rr,...,rr: Shows the route information in 2 hexadecimal digits and ASCII characters. Value: 00h to FEh, number of relay stations maximum 10 units

- With Formats 1 and 3, the route information is entered directly in the command.
- With Formats 2 and 4, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- Formats 3 and 4: To fix the changed channel in the EEPROM, attach the '/W' option.

Example: Change the channel of the target station equipment number = 8F to 14ch (0E) channel. The relay stations are 01, 02, and 03.



・Source station 5F status

①Issue the extended command
Format 1:@DT 05 @CH0E /C 01,02,03,8F CRLF
Format 2:@DT 05 @CH0E /C CRLF

②Extended response *DT=05 CRLF

③Channel change request

⑦ACK response (issued after the relay time has elapsed)
*DR=05 @CH0E CRLF

・Target station 8F status

④There is no data receive

⑤Change the channel

⑥ACK return (Channel change completion notice)

◇ ACK response (Source station output)

When the channel of the target station is changed, the change result is output as the ACK response.

• Source station ACK response output (Changed to 14 channel)
*DR = 05 @CH0E CRLF

5.4.5.2 '@DTxx@CHxx/F' Changing channels of multiple stations at once

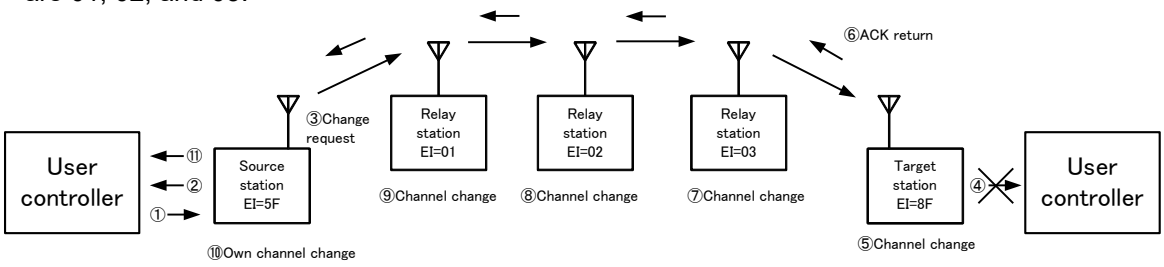
Changes the channels used by multiple specified target stations at once. It is possible to change the channels of the stations and source station entered in the route information at once. The timing by which the channels of the stations are changed is the moment when, after the target stations receive the change channel command from the source station, the ACK responses are received by the various stations. Stations that cannot confirm the ACK signal due to an error remain in their original channel. In this case, investigate the channel range of the system, and change the channels with the target station channel changing command, starting with the most distant stations.

Format 1: '@' + 'DT05' + '@CH' + channel number + '/F' + route information + 'CRLF'
Format 2: '@' + 'DT05' + '@CH' + channel number + '/F' + 'CRLF'
Format 3: '@' + 'DT07' + '@CH' + channel number + '/W' + '/F' + route information + 'CRLF'
Format 4: '@' + 'DT07' + '@CH' + channel number + '/W' + '/F' + 'CRLF'

Details
Format 1: '@DT05' '@CH' cc '/F' rr,rr,...,rr 'CRLF'
Format 2: '@DT05' '@CH' cc '/F' 'CRLF'
Format 3: '@DT07' '@CH' cc '/W' '/F' rr,rr,...,rr 'CRLF'
Format 4: '@DT07' '@CH' cc '/W' '/F' 'CRLF'
cc: Enter the channel number in 2 hexadecimal digits and ASCII characters. Value: 01h to 7Fh
rr,rr,...,rr: Shows the route information in 2 hexadecimal digits and ASCII characters. Value: 00h to FEh, number of relay stations maximum 10 units

- With Formats 1 and 3, the route information is entered directly in the command.
- With Formats 2 and 4 transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- Formats 3 and 4: To fix the changed channel in the EEPROM, attach the '/W' option.

Example: Change the channel of the target station equipment number = 8F to 14ch (0E) channel. The relay stations are 01, 02, and 03.



・Source station 5F status

①Issue the extended command
Format 1:@DT 05 @CH0E /F 01,02,03,8F CRLF
Format 2:@DT 05 @CH0E /F CRLF

②Extended response *DT=05 CRLF

③Channel change request

⑩Change the own channel

⑪Control response
*CH=0E CRLF
(Output when the target station channel is changed)

・Target station 8F status

④There is no data receive

⑤Change the channel

⑥ACK return (Channel change completion notice)

◇ Control response (Source station output)

When the channels of the equipment in the system are changed, a control response is output as the change completion result.

• Source station control response output (changed to 14 channel)
*CH = 0E CRLF

5.4.5.3 '@DT05@CTxx/C' Issue target station test data

Issues link test data from the specified target station for the time specified with the count value.
The transmission data is the 'CRLF' sent repeatedly, and the receive response of the receiving station is '*DR=00'. If there is any input data during transmission, the data is transmitted. Note that once continuous data is issued from the target station, it cannot be stopped by radio.

Format 1: '@' + 'DT05' + '@CT' + count value + '/C' + route information + 'CRLF'
Format 2: '@' + 'DT05' + '@CT' + count value + '/C' + 'CRLF'

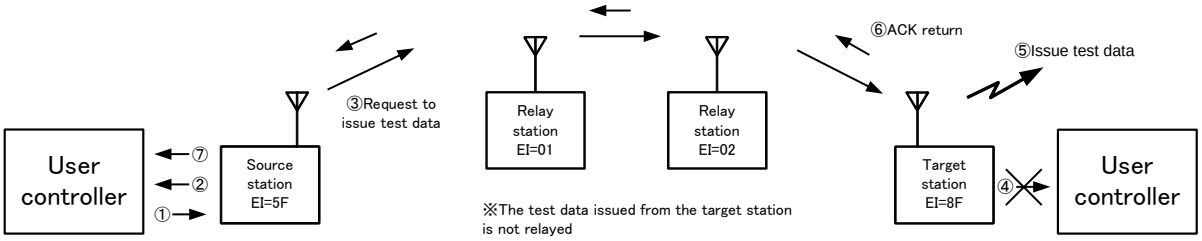
Details
Format 1: '@DT05' '@CT' xx '/C' rr,rr,...,rr 'CRLF'
Format 2: '@DT05' '@CT' xx '/C' 'CRLF'

xx:	Count value: ASCII code that expresses 01h to FFh The count value is 10 seconds per count. The maximum value is FFh, 2,550 seconds.
rr,rr,...,rr:	Shows the route information in 2 hexadecimal digits and ASCII characters. Value: 00h to FEh, number of relay stations maximum 10 units

The count value is 10 seconds per count. The maximum value is FFh, 2,550 seconds.

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or in the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.

Example: Issue a test signal for 60 seconds from the target station equipment number = 8F. The relay stations are 01 and 02.



・Source station 5F status

①Issue the extended command
Format 1:@DT 05 @CT 06 /C 01,02,8F CRLF
Format 2:@DT 05 @CT 06 /C CRLF

②Extended response *DT=05 CRLF

③Request to issue test data

⑦ACK response (issued after the relay time has elapsed)
*DR=05 @CT06 CRLF

・Target station 8F status

④There is no data receive

⑤Issue test data for 60 seconds

⑥ACK return (Test data issue completion notice)

◇ ACK response (Source station output)

When test data is issued from the target station, the issue completion result is output as an ACK response.

• Source station ACK response output
*DR = 05 @CT06 CRLF

5.4.5.4 @DT03@SR/C Reset the target station

Resets the specified target stations. Resetting means returning the MU-4 to the status when the power was turned on. The user starts it up with fixed settings in the EEPROM.

Format 1: '@' + 'DT03' + '@SR' + '/C' + route information + 'CRLF'
Format 2: '@' + 'DT03' + '@SR' + '/C' + 'CRLF'

Details
Format 1 '@DT03' '@SR' '/C' rr,rr,...,rr 'CRLF'
Format 2 '@DT03' '@SR' '/C' CRLF'
rr,rr,…,rr: Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.

Example: Reset the target station equipment number = 8F. Relay stations 01, 02, and 03.
- Source station status
  Extended command: @DT 03 @SR /C 01,02,03,8F CRLF or @DT 03 @SR /C CRLF
  Extended response: *DT = 03 CRLF
  ACK response with regard to the data transmitted from the target station:
  *DR = 03 @SR CRLF

- Target station status
  There is no response.

5.4.5.5 @DT03@SR/F Resetting multiple stations at once

Resets the specified stations. Resetting means returning the MU-1 to the status when the power was turned on. The user starts it up with fixed settings in the EEPROM.
It is possible to reset the stations and source station entered in the route information. The timing by which the stations are reset is the moment when, after the target stations receive the reset command from the source station, the ACK responses are received by the various stations. Stations that cannot confirm the ACK signal due to an error are not reset.

Format 1: '@' + 'DT03' + '@SR' + '/F' + route information + 'CRLF'
Format 2: '@' + 'DT03' + '@SR' + '/F' + 'CRLF'

Details
Format 1 '@DT03' '@SR' '/F' rr,rr,...,rr 'CRLF'
rr,rr,…,rr: Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.

Example: Reset the target station equipment number = 8F, relay stations 01, 02, 03, and the source station.
- Source station status
  Extended command: @DT 03 @SR /F 01,02,03,8F CRLF or @DT 03 @SR /F CRLF
  Extended response: *DT = 03 CRLF
  Control response: *SR = 00 CRLF

- Target station status
  There is no response.

5.4.6 Receive response

When issuing the monitor command and extended command, processing is performed at the target station and the result is returned to the source station. This processing result is output from the source station as a data receive. The content of the receive response depends on the command issued. For details, refer to the explanation of the relevant command.

5.4.7 ACK response

When issuing the extended command and so on, an 'ACK' is returned to show that the target station received the command. This 'ACK' is output from the source station as an ACK response. The content of the ACK response depends on the command issued. For details, refer to the explanation of the relevant command.

5.4.8 Information response

An information response is returned according to the internal processing of the MU-4.
It is possible to change the display format by issuing the response display mode setting command '@RM = TX' or '@RM = CD'. In the default settings, only the information code is displayed.
The information response will be returned only during command mode.

Format: Prefix + response name + '=' + value + terminator

Prefix: '*' = 2Ah, a code that indicates the start of the response string.
Response name: The 2 ASCII characters 'IR'.
Value: Information code shown in the information code list.
Terminator: A code that indicates the end of the command 'CRLF' (0Dh, 0Ah).

Information response example

Response character string	Hexadecimal code actually returned from the MU-4
*IR = 02 CRLF	2A,49,52,3D,30,32,0D,0A

Example:

1. When the command '@RM = CD' is issued
*IR = 02 CRLF

2. When the command '@RM = TX' is issued
*IR = 02: EEPROM System data error CRLF

Information code list

Code	Description
02	EEPROM System data error

*For details of this error, refer to '4.11 EEPROM readout error'.

5.4.9 Error response

If there is an error in the format of the transmit command or control command issued, an error code of the type shown below is sent in response.
These error codes are required during product development, but you should ensure that errors do not occur with your product.
It is possible to change the display format by issuing the response display mode setting command '@RM = TX' or '@RM = CD'. In the default settings, only error codes are displayed.

Format: Prefix + response name + '=' + value + terminator

Prefix: '*' = 2Ah, a code that indicates the start of the response string.
Response name: The 2 ASCII characters 'ER'.
Value: Error code shown in the error code list.
Terminator: A code that indicates the end of the command 'CRLF' (0Dh, 0Ah).

Error response code

Response character string	Hexadecimal code actually returned from the MU-4
*ER = 1D CRLF	**2A,45,52,3D,31,44,0D,0A**

Example: Error response when the '@BR' command is issued

1. When the command '@RM = CD' is issued
   *ER = 0A CRLF

2. When the command '@RM = TX' is issued
   *ER = 0A : BR command format error CRLF

Error code list

Code	Description	Meaning
01	Issued command is not found	The issued command does not exist
02	Channnel data error	The specified channel is outside the range
03	CH command error	Use a 2-digit Hex character for the 'CH' command
04	CH command format error	The 'CH' command format is wrong
05	DT command error	Use a 2-digit Hex character for the 'DT' command
06	DT command format error	The 'DT' command format is wrong. Check the data size.
07	-	
08	RA command format error	The 'RA' command format is wrong
09	RM command format error	The 'RM' command format is wrong
0A	BR command format error	The 'BR' command format is wrong
0B	-	
0C	MD command format error	The 'MD' command format is wrong
0D	DI command error	Use a 2-digit Hex character for the 'DI' command
0E	DI command format error	The 'DI' command format is wrong
0F	EI command error	Use a 2-digit Hex character for the 'EI' command
10	EI command format error	The 'EI' command format is wrong
11	TC command format error	The 'TC' command format is wrong
12	TB command format error	The 'TB' command format is wrong
13	Command input time exceeds limit	The time limit for inputting the command was exceeded
14	-	
15	CT command format error	The 'CT' command format is wrong
16	-	
17	UI command error	Use a 4-digit Hex character for the 'UI' command
18	UI command format error	The 'UI' command format is wrong
19	CS command format error	The 'CS' command format is wrong
1A	PB command format error	The 'PB' command format is wrong
1B	SB command format error	The 'SB' command format is wrong
1C	-	
1D	-	
1E	RT command format error	The 'RT' command format is wrong
1F	IZ command format error	The 'IZ' command format is wrong
20	SR command format error	The 'SR' command format is wrong
21	RI command format error	The 'RI' command format is wrong
22	SN command format error	The 'SN' command format is wrong
23	-	
24	-	
25	RC command format error	The 'RC' command format is wrong
26	SI command format error	The 'SI' command format is wrong
27	RR command format error	The 'RR' command format is wrong
28	RW command format error	The 'RW' command format is wrong
29	RA command format error	The 'RA' command format is wrong
2A	-	
2B	-	
2C	-	
2D	EC command format error	The 'EC' command format is wrong
2E	-	
2F	-	
30	UART Over Run error	
31	UART Framing error	
32	UART Parity error	
33	-	
34	-	
34	-	
36	-	
37	-	
38	TR command format error	The 'TR' command format is wrong
39	TR data input port off	The transparent mode is not set

40	EEPROM block0A even address damage	Even address in the EEPROM Block 0A is corrupted
41	EEPROM block0A odd address damage	Odd address in the EEPROM Block 0A is corrupted
42	EEPROM block0B even address damage	Even address in the EEPROM Block 0B is corrupted
43	EEPROM block0B odd address damage	Odd address in the EEPROM Block 0B is corrupted
44	EEPROM block1 even address damage	Even address in the EEPROM Block 1 is corrupted
45	EEPROM block1 odd address damage	Odd address in the EEPROM Block 1 is corrupted
46	EEPROM block2 even address damage	Even address in the EEPROM Block 2 is corrupted
47	EEPROM block2 odd address damage	Odd address in the EEPROM Block 2 is corrupted
48	EEPROM block3 even address damage	Even address in the EEPROM Block 3 is corrupted
49	EEPROM block3 odd address damage	Odd address in the EEPROM Block 3 is corrupted
50	EEPROM block0A even address correct	Even address in the EEPROM Block 0A has been corrected
51	EEPROM block0A odd address correct	Odd address in the EEPROM Block 0A has been corrected
52	EEPROM block0B even address correct	Even address in the EEPROM Block 0B has been corrected
53	EEPROM block0B odd address correct	Odd address in the EEPROM Block 0B has been corrected
54	EEPROM block1 even address correct	Even address in the EEPROM Block 1 has been corrected
55	EEPROM block1 odd address correct	Odd address in the EEPROM Block 1 has been corrected
56	EEPROM block2 even address correct	Even address in the EEPROM Block 2 has been corrected
57	EEPROM block2 odd address correct	Odd address in the EEPROM Block 2 has been corrected
58	EEPROM block3 even address correct	Even address in the EEPROM Block 3 has been corrected
59	EEPROM block3 odd address correct	Odd address in the EEPROM Block 3 has been corrected

Caution: The error codes for the CA, CP, and CR commands are the DT command errors 05 and 06.

Chapter 6 How to Develop a Program

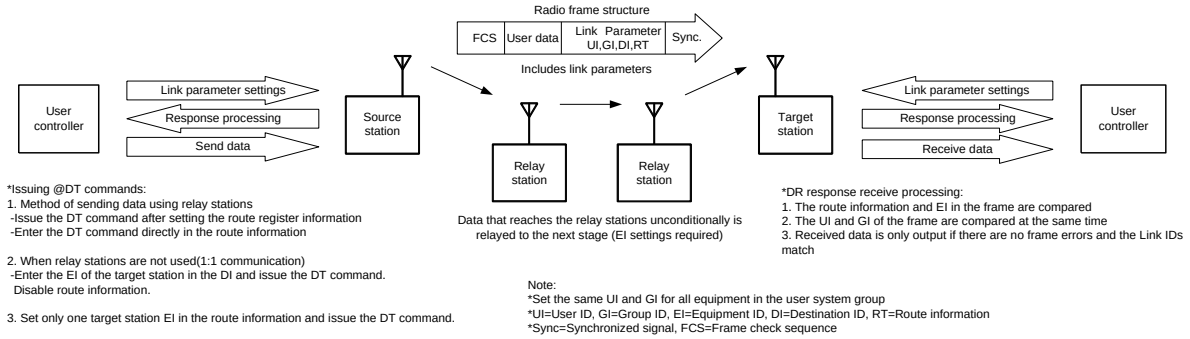
Control of the MU-4 is performed by issuing commands and processing the subsequent response (including the data receive at the target station).
The MU-4 has 3 modes, however the only mode required for making practical applications is the command mode.
This chapter explains the items necessary for developing a user program, focusing on the command mode.

The purpose of the MU-4 is to provide the basic components for communication in order to enable various types of equipment to use radio.
For this reason it is necessary to build communication protocols (ARQ, MCA and so on) into the user application in accordance with the particular application.

*ARQ: Automation Repeat request MCA: Multi-Channel Access

6.1 Outline of User Processes

The outline of how the user controls the MU-4 is explained using one-way communication as an example.



When using the MU-4 to transmit data, it is first necessary to perform various initial settings. When an MU-4 setting command is issued, a command response corresponding to the command is always returned from the MU-4. Process the command response as necessary. In addition, when data is received from the source station, a data receive is output from the target station, so perform receiving process according to its data size.

In order for the target station to receive the data transmitted from the source station, it is necessary to set the link parameters. When the data transmission command is issued, the link parameters are placed in the actual wireless data frame and are processed appropriately by each station. Since the data is not addressed to it, the relay station simply relays the data unconditionally. If there is no data error, it is output to the user controller by the target station as the data receive.
In order to ensure reliable transmission of data, use the data transmission command that has an ACK response.
In addition, when the status of radio waves in the channel being used is poor, it is possible to change the channel of each station using the relay function with an extended command.
There is also a convenient data transmissoin command for outputting the same user data from the relay stations as well.

6.2 The Operations of the MU-4

1. The radio transmission rate of the MU-4 is fixed at 4,800 bps. Note that this is different from the rate of the UART (RS232C) interface. In addition, to achieve communication, besides the user data, data consists of a frame structure with a preamble, control data, error checking data and so on added. For this reason the effective rate for radio transmission is 3,400 bps.
   When the error correction protocols are used, the effective bit rate is approx. 2,300 bps due to error correction processing.

2. RTS and CTS hardware flow control is used for the serial interface of the MU-4.
   The RTS signal is the output signal from the MU-4 to the user system, and when RTS is Low the MU-4 can receive data.
   When RTS is High, the internal data buffer is full and it cannot receive.
   The CTS signal is the input signal from the user system, and when CTS is Low the MU-4 can output data.
   When CTS is High, data output stops.

3. The modes (command, text, binary) of the MU-4 are switched as follows.
   a. Switching between the command mode and binary mode
      To switch from the command mode to the binary mode, issue the '@MD BI' command, then set the MODE terminal to Low. To switch from the binary mode to the command mode, set the MODE terminal to High.
   b. Switching between the command mode and text mode
      To switch from the command mode to the text mode, issue the '@MD TX' command, then set the MODE terminal to Low.
      To switch from the text mode to the command mode, set the MODE terminal to High.
      To switch from the text mode to the command mode with the MODE terminal at Low, issue the ESC code (escape code: 1Bh).

4. Operations when the power is turned on
   After the MU-4 is turned on, it takes 100 ms for internal operation to become stable.
   During this interval it cannot receive commands.

5. When transmitting and receiving user data frames, the MU-4 outputs only frame data that is received correctly from UART, and discards frame data that experiences radio transmission errors. There is no response issued for such frames.

6.3 Command Transmission

Note Do NOT use commands other than those specifically for the MU-4.

6.3.1 Issuing commands

It is possible to feed the characters of a command such as '@CH 03 CRLF' to UART sequentially.
* @: @ (40h) = prefix CRLF: CR (0Dh) = carriage return, LF (0Ah) = line feed

a. With the on-board CPU

To issue a command, first prepare the command data, then feed it to UART 1 byte at a time from the beginning. Since UART applies transmission interrupt with each byte transmitted, ensure that all bytes of the command are transmitted within that routine.
Example: with '@CH 20 CRLF'
As transmission interrupt is applied automatically when the first '@' is sent with discretionary timing, ensure that the next byte 'C' is sent within the transmission interrupt routine. In order to stop transmission interrupt when all the characters within the command have been sent, obtain a suitable command size including a terminator, and keep the number of transmissions within that size.

b. With a program for OSs such as Windows

Feed already prepared command strings to an RS232C processing component or the like.

6.3.2 Issuing data transmit commands

Example: with the 5-byte transmission data '#%&45'.

Make the command string '@DT 05 #%&45 CRLF'
First obtain the 2 digit hexadecimal value for the number of bytes of the transmission data (#%&45), and enter the '@DT' command data size component in ASCII characters. The response is '*DT= 05 CRLF'.

The MU-4 can send data with a size of 255 bytes or less at one time, although internally it has a 255-byte double buffer structure. In addition, although the mode is normally the receive mode, when user data is sent to one side of the buffer, the MU-4 switches to the transmit mode and starts radio transmission. When transmission ends, the MU-4 returns to the receive mode.

If the next user data is sent when user data is being transmitted, the MU-4 does not return to the receive mode and enters the continuous transmission mode. This enables efficient cyclic data transmission and transmission of data that exceeds 255 bytes.
In other words, after sending data with the '@DT' command, and after confirming the '*DT' response, the MU-4 will always enter the continuous transmission mode if the next data is sent within the time found with the following equation. If this time is exceeded, the MU-4 returns to the receive mode.

Time for sending the next data = within 5 ms + 2.08 ms × amount of user data

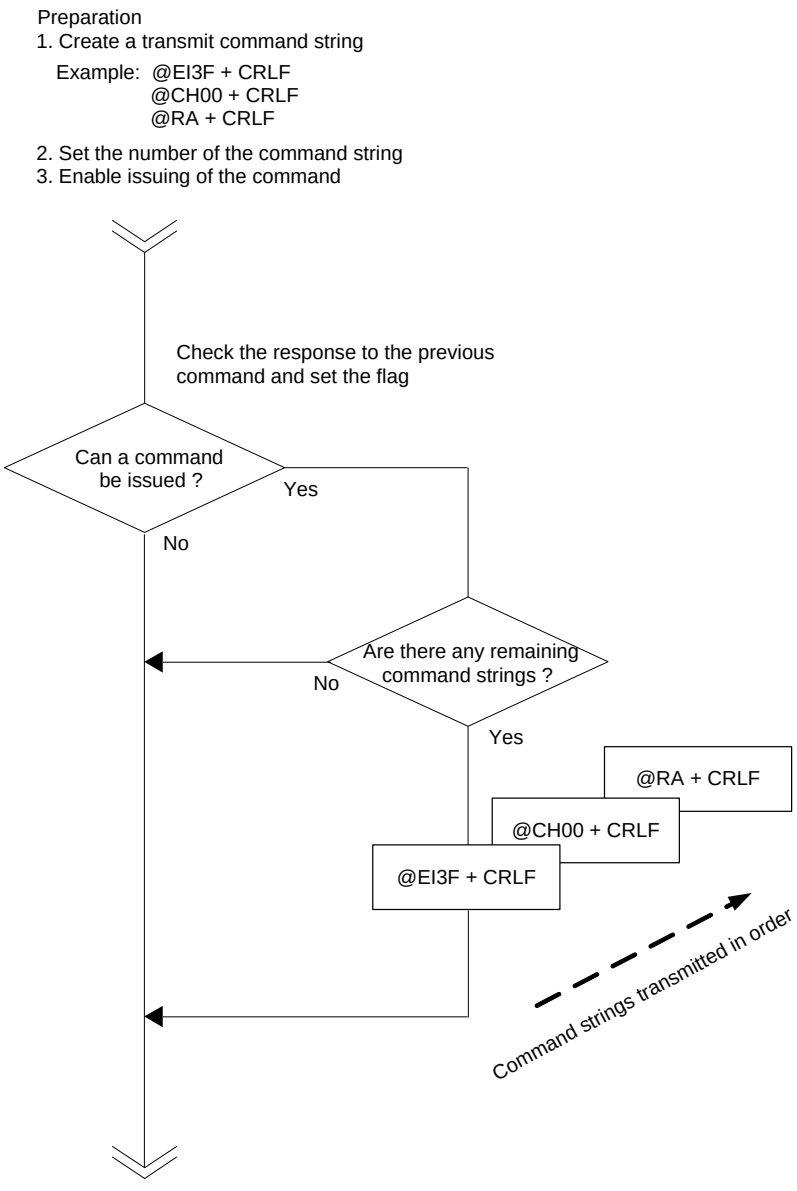
* Hardware flow control operates to control sending of the data.

6.3.3 Issuing commands continuously

You cannot issue commands successively as in '@CH03CRLF@EI33CRLF@DI05CRLF'. In other words, there is always one response corresponding to one command, and the next command should not be issued until this response has been confirmed.
The procedure is as follows.

1. Issue the command '@CH 03 CRLF'. Confirm (process) the response '*CH = 03 CRLF'
2. Issue the command '@EI 33 CRLF'. Confirm (process) the response '*EI = 33 CRLF'
3. Issue the command '@DI 05 CRLF'. Confirm (process) the response '*DI = 05 CRLF'

Process for issuing commands continuously



6.3.4 Issuing commands continuously (when ignoring the response)

As shown in the timing diagram in Chapter 7, a response is returned for each command after a certain period of time has elapsed.
It is possible to issue commands continuously by ignoring the responses and inserting a wait routine between each command. When using this method, allow plenty of extra time, and test the system thoroughly before commercializing the product.

6.4 Response and Receive Processing

6.4.1 Responses and receives

Responses and receives are returned by the MU-4 in the following cases.
1. When a command is issued (command response, error response)
2. Processing result from the target station corresponding to the issued command (receive reponse, ACK response)
3. When data from the source station is received (data receive)

6.4.2 Response and receive formats

All responses and receives start with the prefix '*', and the command response name is the same 2 ASCII characters as the corresponding command. The '*DR', '*DC' and '*DS' receives indicate the transmitted data, and they correspond to the transmitting end '@DT' command.
After the 2 character response or receive name comes '=', followed by bytes that indicate a parameter, value or data. At the end of the response and the receive, the 2 character terminator CRLF (0Dh, 0Ah) is appended.

Example: *CH = 1B CRLF *EI = 30 CRLF *DR = 0B 66666666666 CRLF

6.4.3 Response and receive types

Responses and receives consist of the following types, and each type must be processed separately.

1. 2 character response: The response parameter is a 2 character response
   BR, CA, CH, CP, CR, CS, CT, DI, DT, EC, EI, ER, GI, IR, IZ, MD, RA, PB, RM, RR, SB, SI, SR, TB, TC, VR
   Example: Command '@CH 2A CRLF' Response: '*CH = 2A CRLF'
   The value '2A' consists of 2 ASCII characters that express a hexadecimal number.
2. 4 character response: The response parameter is a 4 character response
   UI
   Example: Command '@UI 800F,xxxx CRLF' Response: '*UI = 800F CRLF'
   The value '800F' consists of 4 ASCII characters that express a hexadecimal number.
3. Data receive: Data when data is received by wireless
   Example: When wireless reception data with a 10 (0Ah) value is received.
   Data receive '*DR = 0A 5555555555 CRLF'
   The value '0A' consists of 2 ASCII characters that express a hexadecimal number.
   After the data size comes the corresponding number of bytes of user data.
4. Number of channels × 2 character response: 127ch x 2 character response
   RC
5. 9 character response: The response parameter is a 9 character response
   SN
6. Items for which the response length cannot be regulated
   The response length for RT and VR cannot be regulated.
   These should be determined by their terminator.

6.4.4 Response and receive processing

First, the response and receive data that enters UART from the MU-4 is received by the ring buffer. If there is data in the ring buffer, the response and receive identification routine takes 1 byte at a time and performs interpretation of the response and the receive. After, the processing routines diverge in accordance with each response or receive.

To determine the response and receive type, prepare a table of all responses and receives, and make a comparative judgement. It is convenient to return the result of comparison as an integer of the response or receive position on the table, and for the value to diverge to the processing routine.
Arrange the responses and receives in the table divided into groups by type.

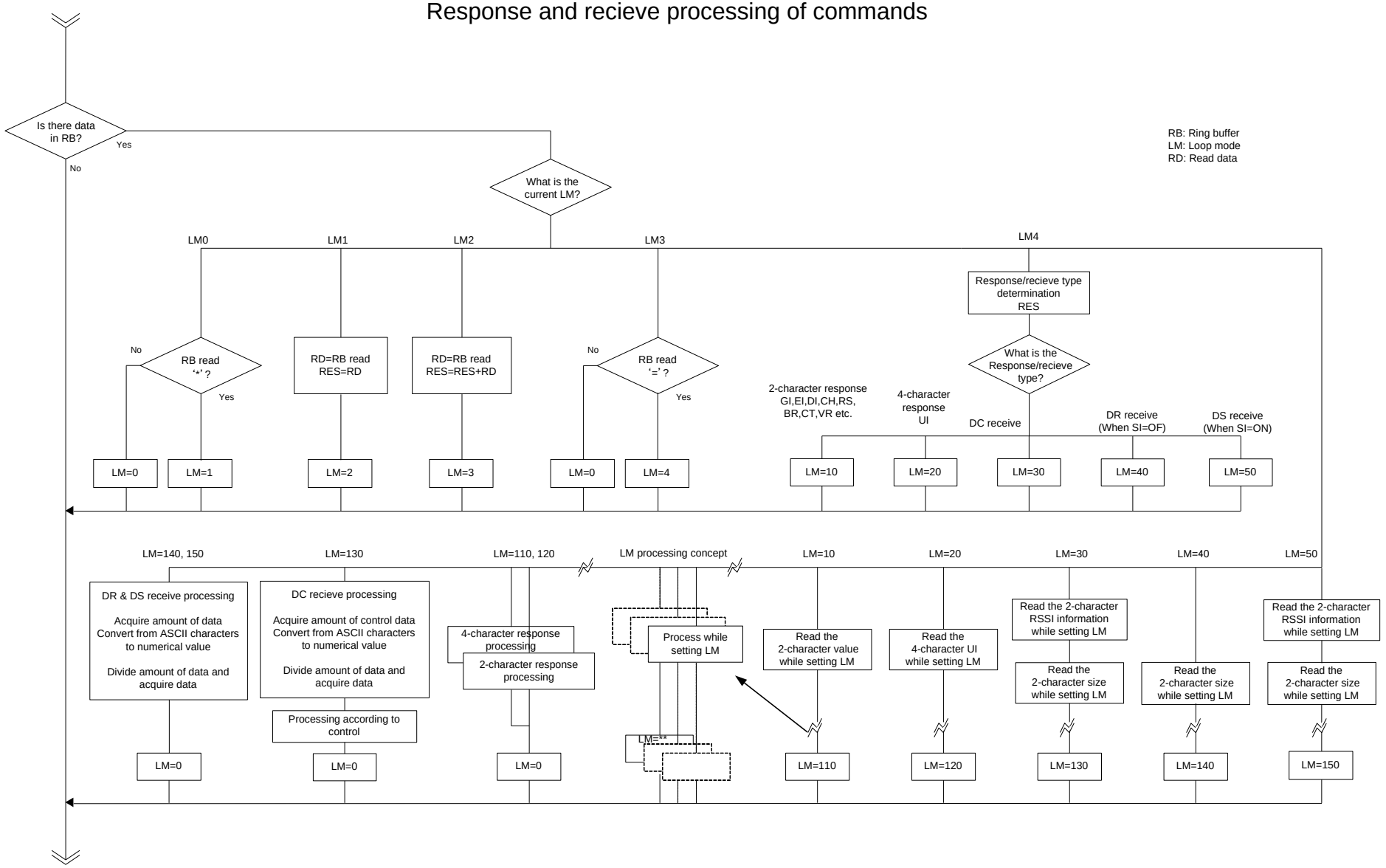
Example:
array [‘BR’, ‘CH’, ‘CS’, ‘CT’, ‘DI’, ‘DR’, ‘DT’, ‘EI’, ‘ER’, ‘GI’, ‘IR’, ‘MD’, ‘PB’, ‘RA’, ‘RM’, ‘SB’, ‘TC’, ‘TB’, ‘UI’, ‘VR’]

Response and receive values are ASCII strings that express a numerical value, so when using values, provide a routine to convert the ASCII characters into numerical values. For example, when data is received, the ‘*DR’ data receive value indicates the amount of user data received, so this is converted to a numerical value and only that amount of data is obtained.

Main loop

Start in loop mode(LM=0)

Response and recieve processing of commands



6.5 Creating an Air Monitoring Function

The air monitoring function such as the one in the Evaluation Program obtains the RF input level of the receiver and monitors the radio wave status of the field.
The MU-4 can get the RSSI level of the designated channel by issuing the RSSI absolute level measurement command '@RA'.
The air monitoring function can be achieved by designating a special ID for obtaining the RSSI level as the Equipment ID (EI = FFh), and outputting the RSSI level to the graph-making component or similar function while obtaining the RSSI level of each channel sequentially.

* When the Equipment ID of the MU-4 is EI=FFh, the system is reserved so the MU-4 performs special operations. When the Destination ID is ID=FFh, data cannot be transmitted, and when the Equipment ID is EI=FFh, even if the link parameter matches, received data is not output. Instead, the RSSI (radio field intensity) of the current channel can be read out with the '@RA' command.

The procedure is as follows.
1. Issue the command '@EI FF'
   This setting is made only once at the beginning.
2. Issue the command '@CH xx'
   Designate a channel for which to acquire the RSSI level. 'xx' is the hexadecimal value that indicates the channel.
3. Issue the command '@RA'
   This acquires the RSSI level.
4. The RSSI level acquired is output as graph components or similar data.
5. Repeat steps 2 to 4.

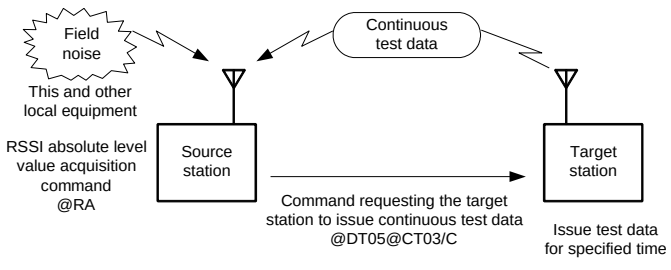
Note: Be sure to confirm the response to the '@CH' command issued first before issuing the '@RA' command.

6.6 Assessing the Field Status for Communication

With applications that use the MU-4, in the development stage or when development is complete and the unit is actually used, it is necessary to assess the field status of the system at all times for stable communication. In other words, in the development stage when the MU-4 is mounted on the circuit board, it is necessary to consider the pattern design and arrangement of components to extract the optimum values for radio performance, and to ensure stable and reliable communication in operation, it is necessary to measure the state of the radio waves and the surrounding floor noise and to locate the equipment at the optimal point.
The MU-4 has the following commands to allow convenient assessment of these aspects of communication.
1. @RA : Acquisition of the RSSI absolute level of the source station
2. @CR : Acquisition of the RSSI absolute level of the target station (actual signal level and floor noise level)
3. @CP : Packet test

6.6.1 Source station RSSI measurement

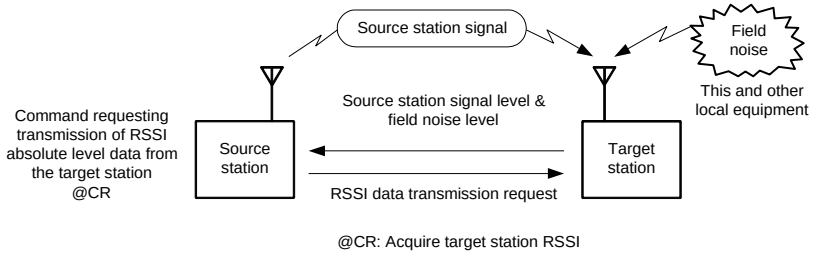
By issuing the @RA command, the RSSI level of the source station can be measured. It is possible to achieve optimization while measuring the high frequency noise from the unit itself and from peripheral equipment, and the signal level from the source station. To measure the signal level from the target station, it is possible to issue a command requesting continuous issue of data '@DT 05 @CT xx' from the source station to the target station.



@RA: Acquire source station RSSI

6.6.2 Target station RSSI measurement

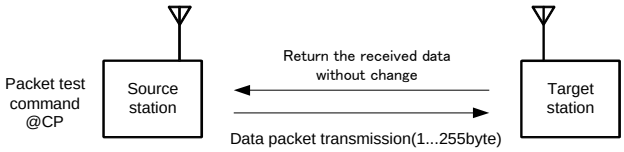
In order to perform stable communication, it is necessary to locate the equipment where a sufficiently high signal level can be obtained.
By issuing the '@CR' command, it is possible to measure the floor noise of the target station and the signal level from the source station and send the information back.



@CR: Acquire target station RSSI

6.6.3 Packet test

When transmitting data packets with the '@CP' command, the data packet is returned from the target station wtihout change. Using this, it is possible to measure the packet success rate corresponding to the field status. A data size between 0 to 255 bytes can be set for each packet with the '@CP' command. In order to locate the equipment in the optimum place, send packets repeatedly with the '@CP' command and measure the packet success rate. Note, however, that the packet transmission procedures and the calculation of success rate must be programmed.



@CP: Packet test

6.7 Achieving Data Transmission

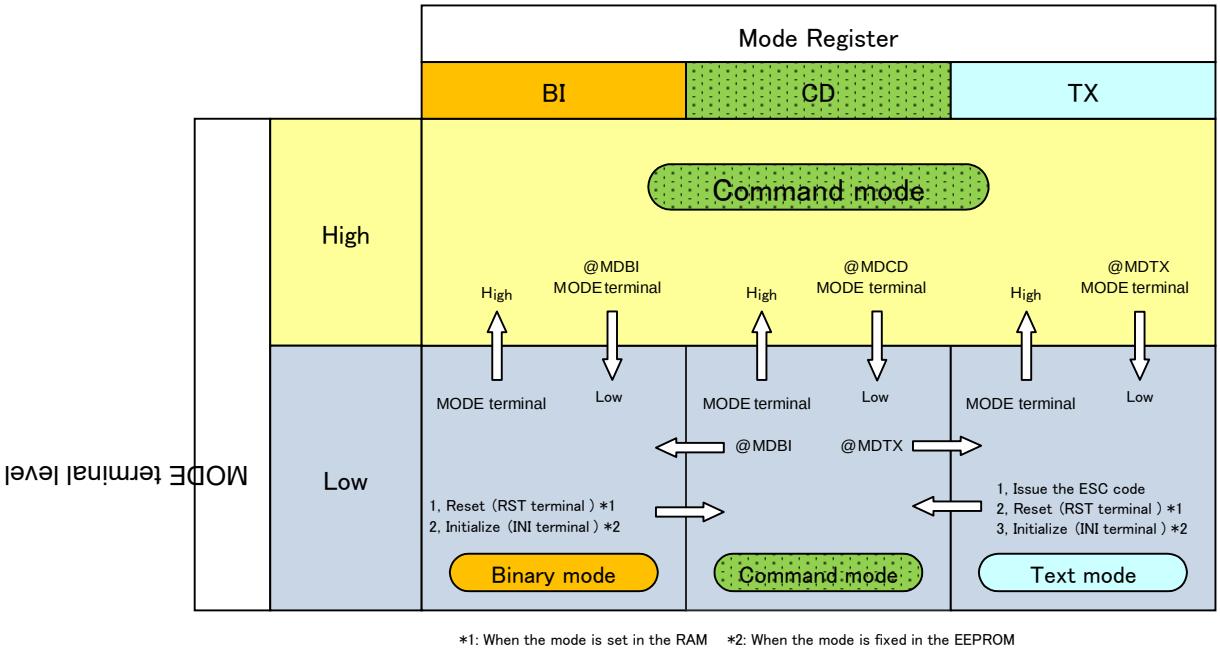
The MU-4 can send data of 255 bytes or less at one time. When transmitting data in excess of 255 bytes, you will need to incorporate a transmission protocol so that, for example, data is split for transmisson.
When transmitting and receiving user data frames, the MU-4 outputs only frames that are received correctly, and discards those frames that experience errors. There is no response issued for dropped frames.
When transmitting large volumes of data such as files, it is performed using two-way communication such as ARQ (Automatic Repeat Request), and it is necessary to provide measures against dropped frames caused by wireless errors. Data frames include frame numbers and the like, and these are used as the criteria for ARQ.

6.8 Operation in Binary Mode

The binary mode of the MU-4 is intended to be used for test communication. Applications that use the MU-4 should basically use the command mode.
However, it is possible to develop simple applications using the binary mode for applications that send less than 255 bytes at a time, if certain conditions are met. This applies only to newly developed applications and does not mean that data output by existing equipment can be sent as is. In other words, the format, timing, and control lines for output data of existing equipment must match the content of this operation guide.

6.8.1 Modes

First, we will explain about the command mode and binary mode. The diagram below is a relational diagram of the MU-4 modes.



BI: binary mode, CD: command mode, TX: text mode

Command mode
There are two ways to set the MU-4 to the command mode, as follows.

1. If the MODE terminal is set to H, the MU-4 is set to the command mode irrespective of the setting in the MU-4 mode register.
2. If the MODE terminal is set to L, when the power is turned on the MU-4 starts in the default mode set in the EEPROM. Depending on the mode, take the following action.
   In the binary mode: Initialize the MU-4.
   In the text mode: Issue the escape code: 'ESC'.

* Initialization method: Set the INI terminal to Low and turn on the power. After turning off the power briefly, open the INI terminal and turn on the power again.

Binary mode
There are two ways to set the MU-4 to the binary mode, as follows.

1. If the MODE terminal is set to H, set the MU-4 mode register to the binary mode with the '@MD BI' command. Then set the MODE terminal to the L level.
2. If the MODE terminal is set to L, when the power is turned on the MU-4 starts in the default mode set in the EEPROM. Depending on the mode, take the following action.
   In the command mode: Set the MU-4 mode register to the binary mode with the '@MD BI' command.
   In the text mode: Issue the escape code: 'ESC' and after setting the MU-4 to the command mode, switch modes.

6.8.2 When developing a new system

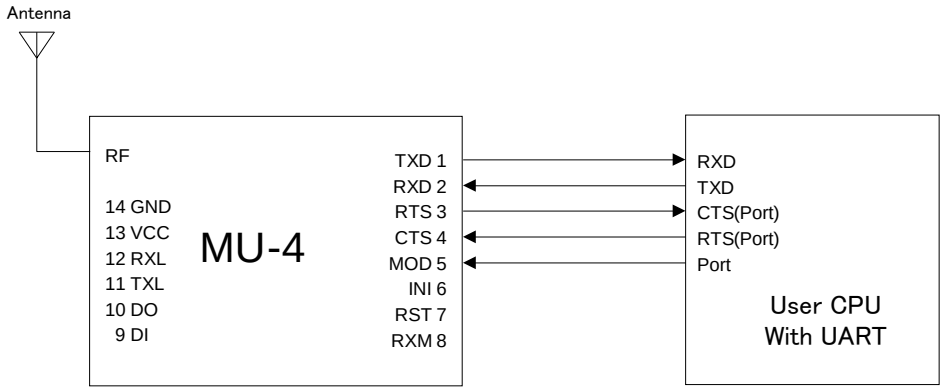
The binary mode of the MU-4 can be used in accordance with the following methods, however when it is used in this mode, it must meet the **"Conditions for use of the binary mode"**, explained later.
Set the MODE terminal to be controlled by the CPU.

1. Using the binary mode while switching between the binary mode and command mode
With applications that must change channels and the destination of transmissions, switch between the command mode and binary mode, using the CPU to control the MODE terminal.

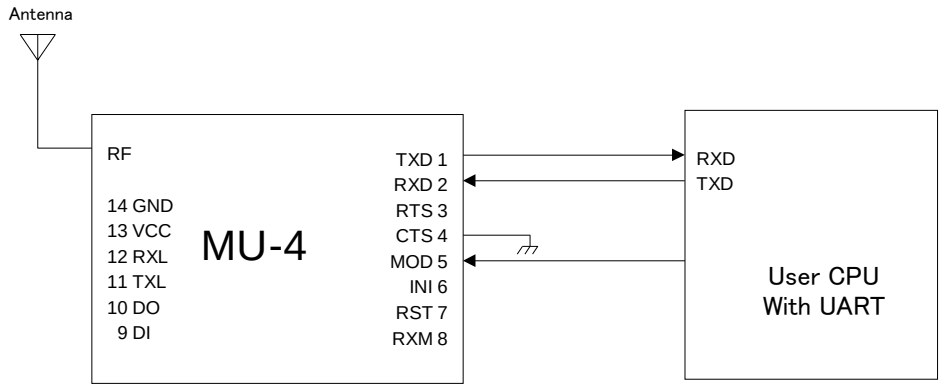
2. Using only the binary mode directly after turning on the power
If you want to use the MU-4 in the binary mode directly after turning on the power of the system, without changing channels or the destination of transmissions, issue the command "@MD BI /W" to set the MU-4 mode register and to fix the mode in the EEPROM. This setting is made only once at the beginning when first using the system. In addition, when turning on the power, set the MODE terminal to L.
Use the command '/W' option to fix the channel, User ID, Destination ID and so on in the EEPROM.

3. Connection example
These are examples of connections in which hardware flow control is used and not used.
Normally with the MU-4, in order to prevent buffer overflow of the data buffer, hardware flow control is fixed as the flow control for serial communication. This also applies to the binary mode. However, if the data to send at one time is less than 255 bytes, data can be sent without performing flow control.
In addition, since the various setting commands of the MU-4 are only a few bytes, there is no particular need for a flow control line.

When using hardware flow control
Set the UART of the control CPU to be controlled by hardware flow control.



When not using hardware flow control
1. Set the CTS terminal to L level, and open the RTS terminal.
2. Set the UART of the control CPU to no flow control.



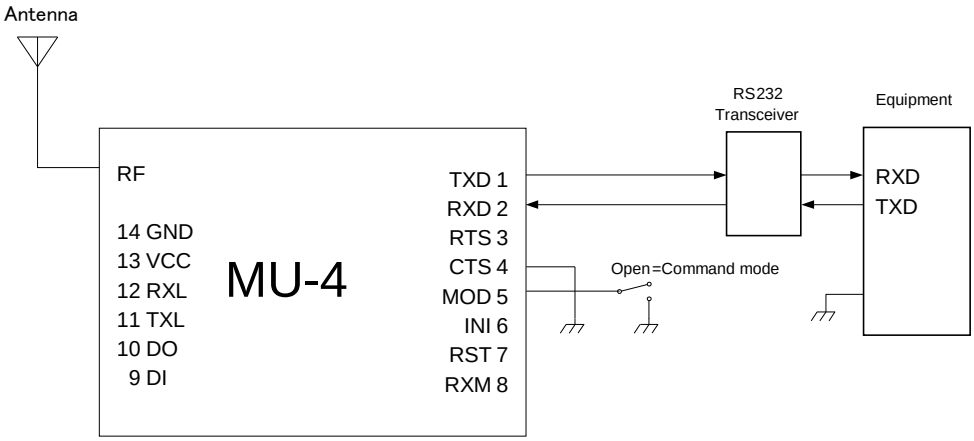
6.8.3 When using only the data line of existing equipment

Caution is necessary when using the MU-4 connected to existing RS232C equipment.
Although RS232C has regulations for its own data format, use of the control line differs depending on the equipment. Equipment that was previously connected with a cable cannot just be connected with the MU-4.
Essentially, the status of the control line can be ignored with only the data line connected, however the data transmission timing and data format of the existing equipment can only be used if it meets the **"Conditions for use of the binary mode"**, explained later.
To check whether these conditions are met, first carry out an investigation using an oscilloscope or the like.

Example of connection
Since the output from existing equipment is normally RS232C, in order to connect to the MU-4, convert the output level with a RS232C transceiver IC. In addition, consider means of enabling the various settings to be made in the command mode.

For example, the following procedure can be used.
1. Provide your circuit board with a socket, and mount the MU-4 after performing the various settings using a dedicated board.
2. Set the MODE terminal of the MU-4 to L or H with the switch, to switch between the command mode and binary mode

.
*Since the various setting commands of the MU-4 are only a few bytes, there is no particular need for a flow control line.



* The MODE terminal is pulled up internally.

6.8.4 Conditions for use of the binary mode

1. Make the size of data sent at one time less than 255 bytes.
2. Data transmission should be timed so that radio transmission of the previously transmitted data is finished completely.

Timing of data transmission
The transmission speed of radio transmission is 4,800 bps, so find the correct timing with the following formula.

Data transmission timing = 36 ms + 2.08 ms × amount of user data + time without input in the binary mode

The start of radio transmission of data follows immediately after the time set with the time without input in the binary mode setting command ('@TB') has elapsed.

3. The internal operation of the MU-4 is unreliable for 100 ms after the power is turned on, so data should not be sent during this interval.
4. During input or when data is being sent to the MU-4, do not switch the MODE terminal

6.9 Error Correction Function

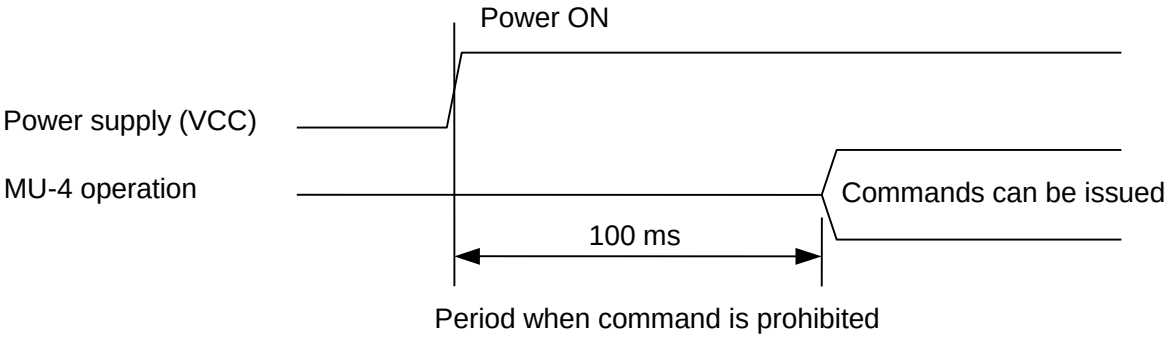
TheMU-4 has error correction protocols for wireless data. This communication protocol is achieved by using Reed-Solomon codes. For communication using the error correction protocols, issue the '@EC' command with the command option'/W'. Enabling the error correction protocol reduces the effective radio communication data rate due to internal processing.

Reed-Solomon code

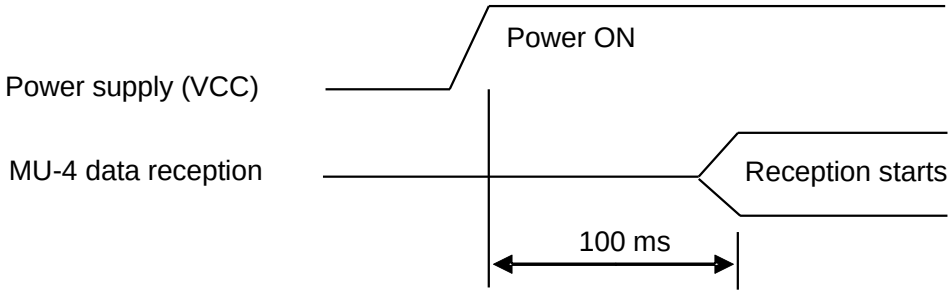
The error correction capability of the Reed-Solomon codes used for the MU-4 is RS (255,247). The error correction in the MU-4 is performed for each control block of the frames sent between radios, and in the data component, errors of up to 4 bytes in 1 block consisting of 32 bytes can be corrected. When transmitting 255 bytes of data, the data component is divided into 8 blocks, enabling error correction of 4 x 8 = 32 bytes. The error correction function is especially effective for burst errors caused by fading between radios.
If errors of more than 4 bytes occur, the packet will be discarded without being corrected.
For data transmission, you do not need to be aware of the blocks. Use the same data transmission commands as used in the standard protocol for data transmission.

Chapter 7 Timing

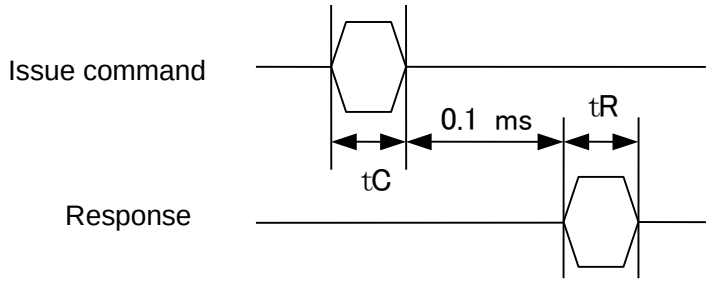
◆Period when issuing commands is prohibited when turning on power



◆ Period until the MU-4 starts reception when turning on power



◆General command and command response timing
(excluding the CH, RA, CS commands)



tC = A× 10000／br　　tR = B× 10000／br

*Units are ms, br=UART bit rate

A=Command length
A=7　: GI,EI,DI,CH,BR,PB,SB,MD,TC,TB,CT,RI,RM,SI,RR,EC
A=5　: VR,SN,SR,IZ,CS,RA,RC
A=14　: UI
A=Number of relay station x 3 + 7 : RT
A=Number of relay station x 3 + 8 : CA, CR

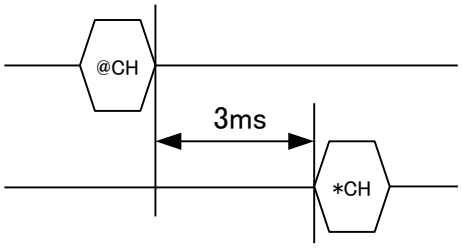
B=Response length
B=8　: GI,EI,DI,CH,BR,PB,SB,MD,TC,TB,CT,RI,RM,SR,IZ,
SI,RR,CS,RA,CA,CR,CP
B=10　: UI

B=15　: SN
B=Number of relay station x 3 + 8 : RT

◆ CH command & command response timing

Issue the @CH command

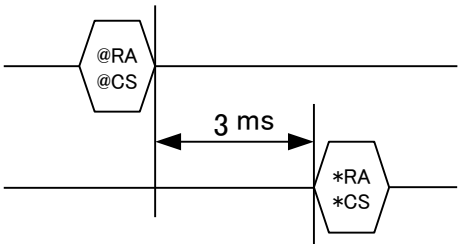
*CH response



◆ RA ,CS command & command response timing

Issue the @RA, @CS command

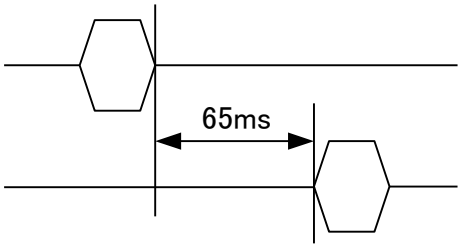
*RA, *CS response



◆ Command & command response timing when /w option is specified

Issue command with /w

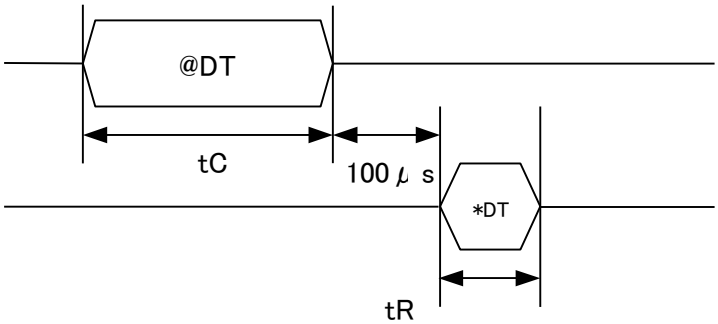
Response



◆ Data transmit command time

Source station
Data transmit command
@DT

Data transmit response
*DT



Data transmit command time tC = N x 10000 / br

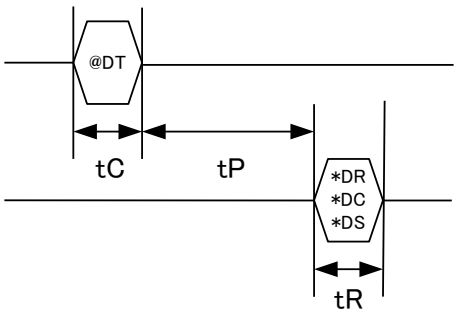
Data transmit response time tR = 8 x 10000 / br

* Units are ms , br = UART bit rate , N = n + o + r + 7,
n = Number of data bytes sent (within 255 bytes), o = Number of command option characters (/A, %R etc.), r = Number of route information characters = Number of relay stations x 3 + 2

◆Transmit and receive time
(no relay function, when 1 frame is transmitted)

Source station
Data transmit command
@DT

Target station
Data receive
*DR,*DC,*DS



*Reference value with 40-byte TX.
tC=(40+7)*10000/9600=49ms
tP=(40*2.08)+46=130ms (standard)
(tP=(40*2.08)+124=208ms (FEC))
tR=(40+8)*10000/9600=50ms
Total=49+130(208)+50=229(307)ms

* UART bit rate=9600bps

Command time tC = (n+7)×10000/br Radio transmission time tP = (n×2.08)+tO
Data receive time tR = (n+8)×10000/br

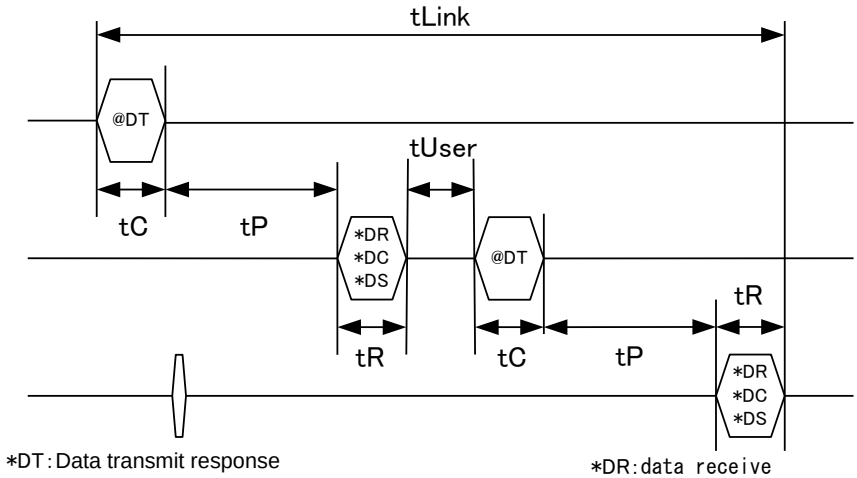
*Units are ms *n = number of data bytes sent (within 255 bytes)
*Br = UART bit rate *TO = Overhead Fig 1.

◆Time to establish link
(no relay function, when 1 frame is transmitted)

Source station
Data transmit command
@DT

Target station
Data receive &
Data transmit command

Source station
Data receive
*DR,*DC,*DS



*DT:Data transmit response
*DR:data receive

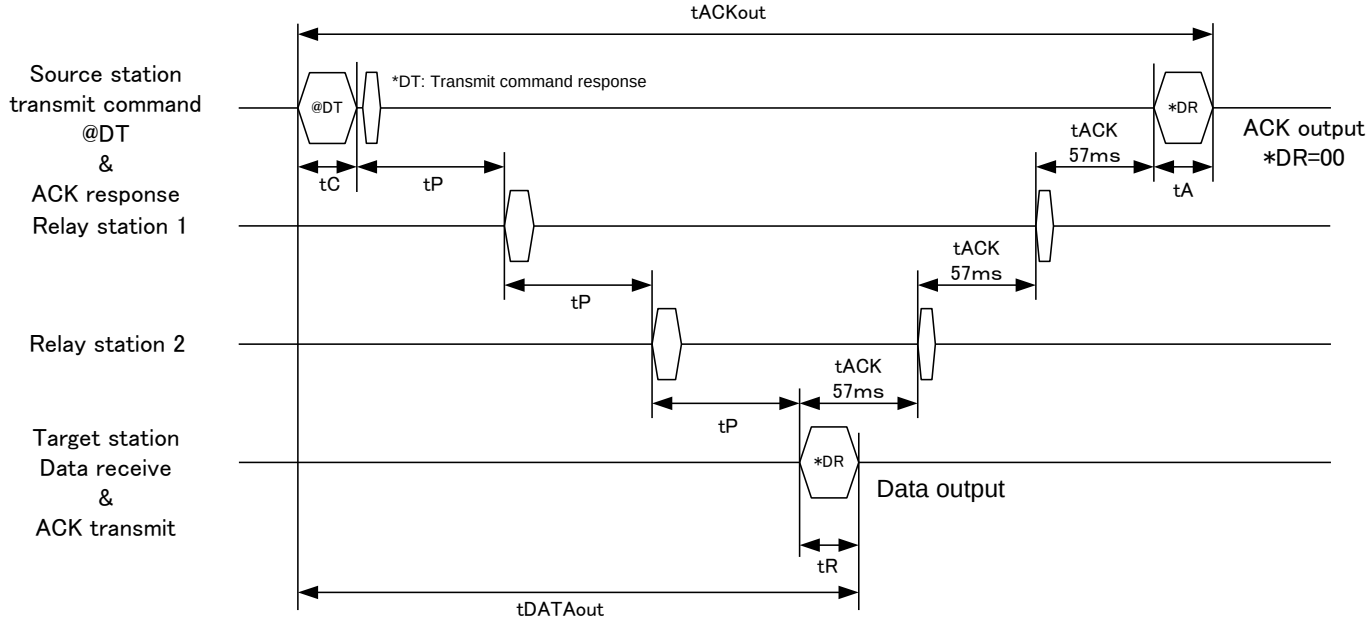
Command time tC = (n+7)×10000/br Radio transmission time tP = (n×2.08)+tO
Data receive time tR = (n+8)×10000/br
tUser = User program processing time tLink = Time to establish link

*Units are ms *n = number of data bytes sent (within 255 bytes)
*bR = UART bit rate *tO = Overhead Table 1
*Reference value with 20-byte link data.
tLink=195ms Conditions:57600bps, without entering tUser

◇Table 1 Overhead:tO

	Communication protocol								
	Standard protocol	Error correction protocol							
Tx data bytes[byte]	1～255	1～32	33～64	65～96	97～128	129～160	161～192	193～224	225～255
tO[ms] Without Error	46	97	114	131	147	164	181	197	214
tO[ms] With Error	46	107	124	141	157	174	191	207	224

◆ Relay function timing (with ACK, when 1 frame is transmitted)



tDATAout = tC + tP･(m + 1) + tR

tACKout = tC + (m + 1)(57 + tP) + tA

Command time tC = (n + 7) × 10000/br

Data receive time tR = (n + 8) × 10000/br

ACK response time tA = 80000/br

Radio transmission time tP
= (n×2.08) + tO + (m×2.08)

＊Units are ms, n=Number of data bytes sent(within 255 bytes), br=UART bit rate,
M=Number of relays (up to 10 units), tO=Overhead Table 2
＊Reference value 1 with 20-byte link data: tDATAout=262 ms, tACKout=429 ms
Conditions: Standard mode, 57,600 bps, 2 relays
＊Data output time when there is no ACK response is calculated with tDATAout

◇Table 2 Overhead:tO

	Communication protocol								
	Standard protocol	Error correction protocol							
Tx data bytes[byte]	1～255	1～32	33～64	65～96	97～128	129～160	161～192	193～224	225～255
tO[ms] Without Error	39	125	142	159	175	192	209	225	242
tO[ms] With Error	39	135	152	169	185	202	219	235	252

Chapter 8 Transparent mode

The MU-4 has a transparent mode in which users can use their own communication protocol as it is.
For data transmission and reception in the transparent mode, use the DI (DATA-IN) and DO (DATA-OUT) terminals.

To set the transparent mode and perform transmission and reception, issue the '@TR' command.
When using the transparent mode, it is recommended the user fix the transparent mode in the EEPROM with the '/W' option when turning the power on and use the MU-4 in the transparent mode only.
For details of the '/W' option, refer to '5.3 Save Setting Command Options'.

8.1 Transparent mode setting

To set the transparent mode, issue the '@TR' command as follows:

The basic command and response formats are the same as that for the control commands and control responses.
For details, refer to '5.4.2 Control commands and control responses'.

Default: OF (Transparent mode is Off)
Value: OF = Transparent mode is Off ON = Transparent mode is On

Example Set the transparent mode
Control command: @TR ON CRLF
Control response: * TR =RX CRLF

Example Set the transparent mode to Off
Control command: @TR OF CRLF
Control response: * TR = OF CRLF

8.2 Data transmission and reception

To transmit/receive data in the transparent mode, issue the '@TR' command as follows:

The basic command and response formats are the same as that for the control commands and control responses.
For details, refer to '5.4.2 Control commands and control responses'.

Default: RX (Reception)
Value: RX = Set to Reception TX = Set to Transmission

Example Transmit the data input at the DI terminal
Control command: @TR TX CRLF
Control response: * TR = TX CRLF

* Ensure that the transparent mode is on with @TR ON(@TR ON/W) before transmission.

Example Receive the data transmitted in the transparent mode at the DO terminal
Control command: @TR RX CRLF
Control response: * TR = RX CRLF

* Ensure that the transparent mode is on with @TR ON(@TR ON/W) before reception.

8.3 Commands valid for transparent mode

8.3.1 Commands which can be used in the transparent mode (when @TR ON is issued)

Command type	Command name	Command
Operation setting	Transparent mode setting	@TR
	Channel setting	@CH
	Antenna power setting	@PW
RSSI information	RSSI absolute level measurement	@RA
	All channel RSSI absolute level measurement	@RC
	Channel status acquisition	@CS
information acquisition	Program version acquisition	@VR
	Serial number acquisition	@SN
UART parameter setting	UART baud rate setting	@BR
	UART parity setting	@TB
	UART stop bit setting	@SB

8.3.2 Commands which cannot be used in the transparent mode (when @TR ON is issued)

The commands listed in the table below cannot be used when the transparent mode is set.
To use them, ensure that the transparent mode is disabled with the @TR OF command.

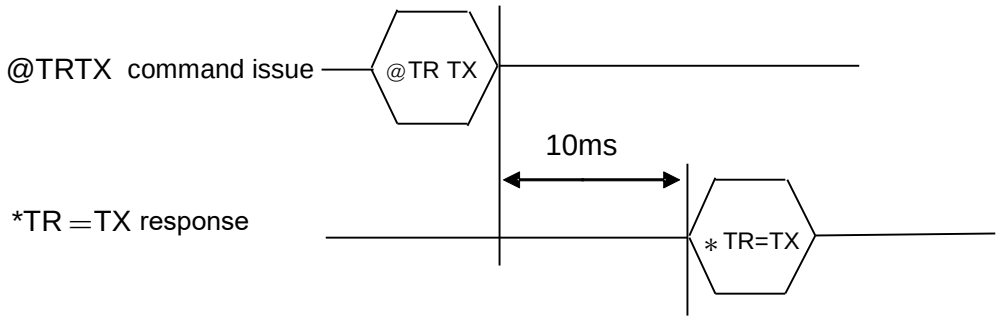
* If the commands below are issued while @TR ON, @TR RX or @TR TX is set, the error response will not be returned.

Command type	Command name	Command
Radio link related setting and acquisition	Data transmit command	@DT
	User ID setting	@UI
	User ID setting	@GI
	Group ID setting	@EI
	Equipment ID setting	@DI
	Destination ID setting	@RT
	Receive route information use setting	@RR
	Error correction protocol setting	@EC
Operation setting	Reset	@RS
	Initialize	@IZ
	Operation mode setting	@MD
	Command mode input waiting time setting	@TC
	Time without input in the binary mode setting	@TB
RSSI information	Target station RSSI absolute level measurement	@CR
	Target station all channel RSSI absolute level measurement	@CA
Test commands	Test data continuous transmission	@CT
	Packet test	@CP

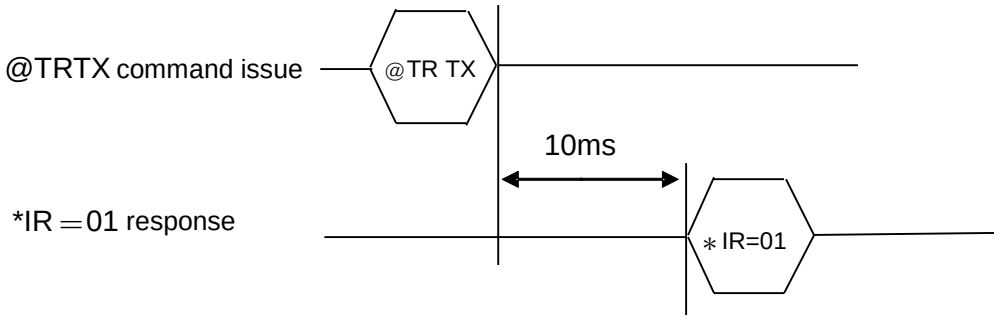
8.4 Timing for '@TR' command

For the timing not listed below, refer to 'Chapter 7 Timing'.

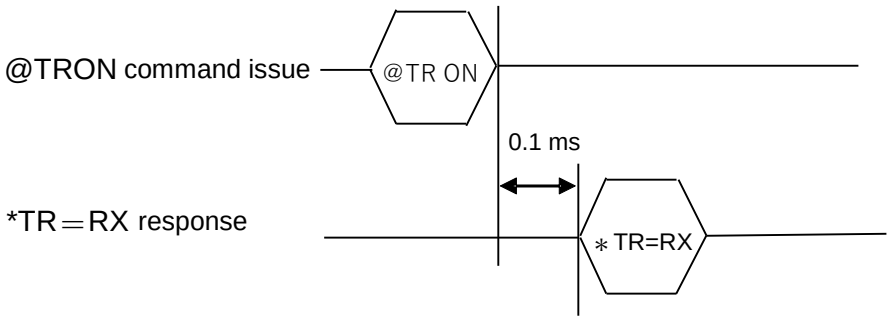
@TR TX command & command response timing



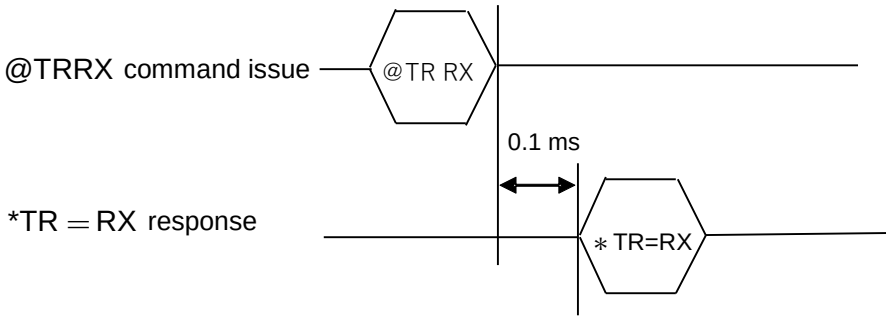
@TR TX command & *IR=01 response timing



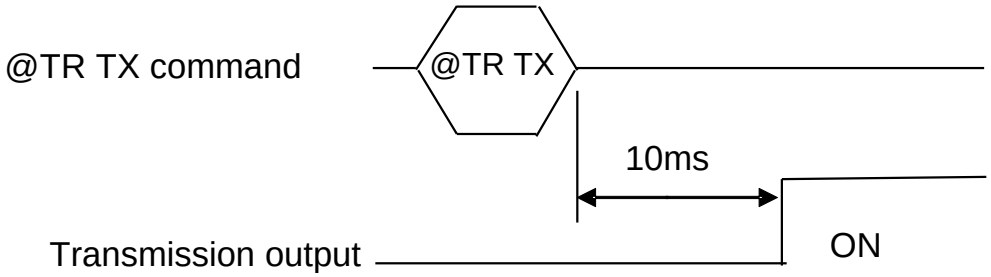
@TR ON command & command response timing



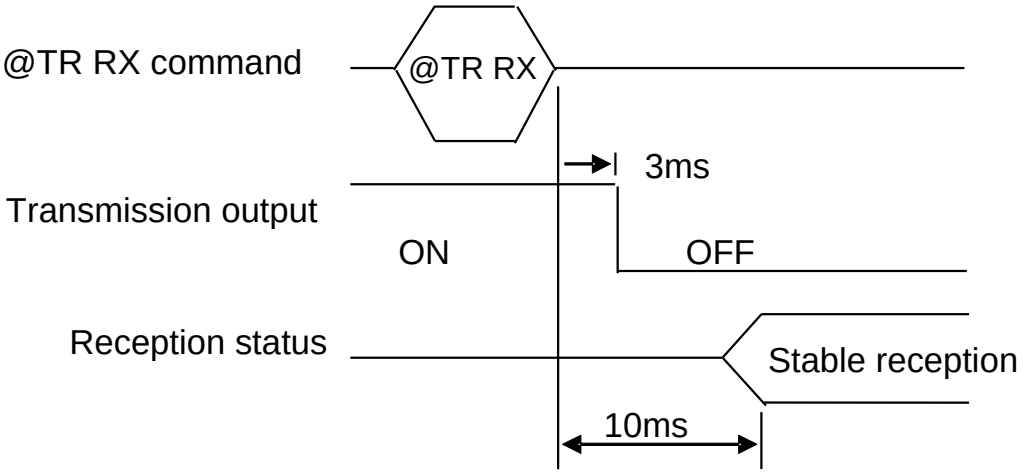
@TR RX command & command response timing



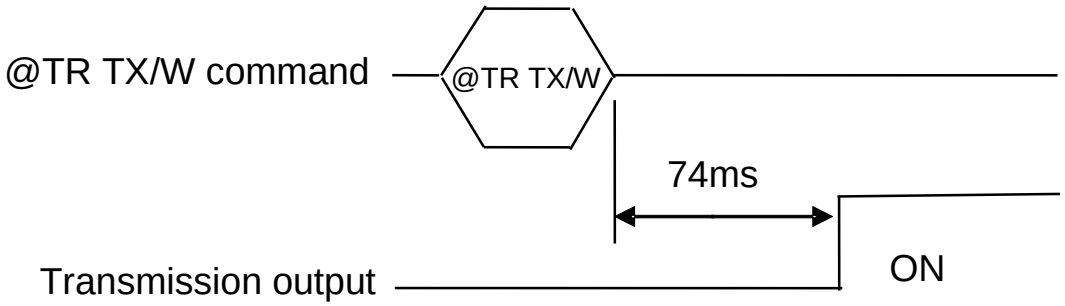
@TR TX: Switching from reception to transmittion



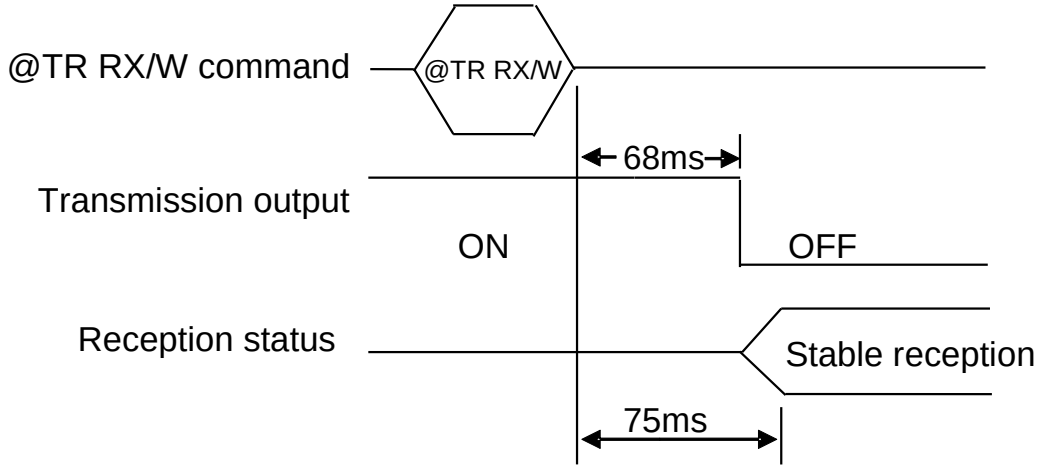
@TR RX: Switching from transmisison to reception



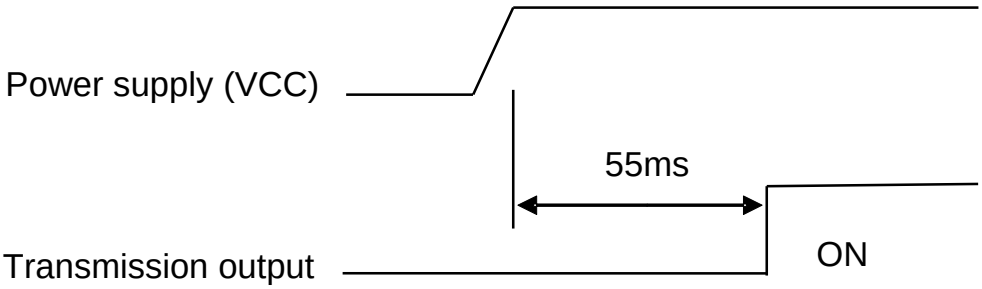
@TR TX/W: Set to transmission and fix in EEPROM with /W option



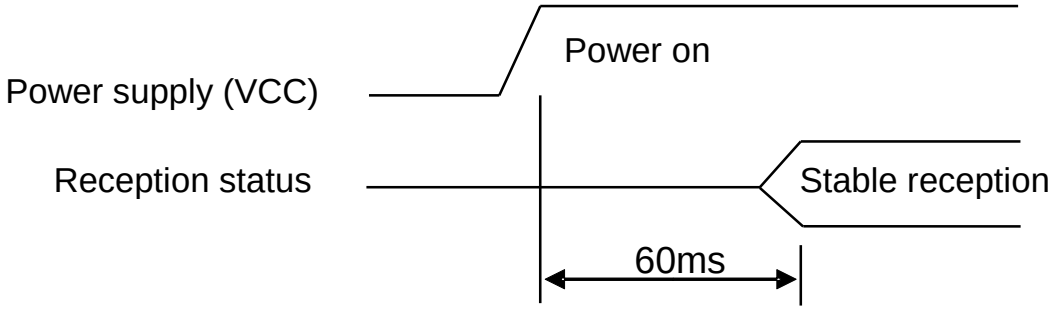
@TR RX/W: Set to reception and fix in EEPROM with /W option



Period until transmission starts when turning on power (when @TR TX/W is set)



Period until reception is stabled when turning on power (when @TR ON/W is set)



8.5 Data format

8.5.1 Data frame structure

When transmitting and receiving serial data in the transparent mode, configure a data frame with a preamble, ID code and so on, to ensure that the necessary data is transmitted.

A general data frame consists of Preamble, ID code, User data and Data-check and is transmitted/received as a packet data. Dummy data is added to the end if necessary.

Preamble
A preamble data is required to match the timing between transmission and reception. At the start of data transmission, the transmitter transmits data including alternate low and high signals for a certain period of time. A recommended preamble pattern is 11001100....of more than 20 ms.

ID code
An ID code is a unique code to identify own system from other systems. The receiver determines if the received data is sent to itself. To avoid erroneous reception, it is recommended to use an ID code with appropriate length.

User data
A user data is data the user intends to send/receive. To prevent data from being garbled, it is recommended that the user data has periodical transitions between 1 and 0.
*With the MU-4, ensure that continuous 1 or 0 is limited to 6 ms or less (28 bits for 4800 bps).

Data-check
A data-check (such as CRC) is used to check if the transferred data has errors or not. The receiver determines if the received data is valid or not.

Dummy data
When transmitting data using UART, there is a time lag from when the last data is set to the transmission register until UART output is actually completed.
If transmission is turned off or switched before the last bit is output, the last bit may be lost.
Such errors can be avoided by adding dummy data to the end of the data frame.
* You can also avoid the last bit from being lost by controlling the timing of turning off transmission or TX/RX switching with the MU-4.

Example data format

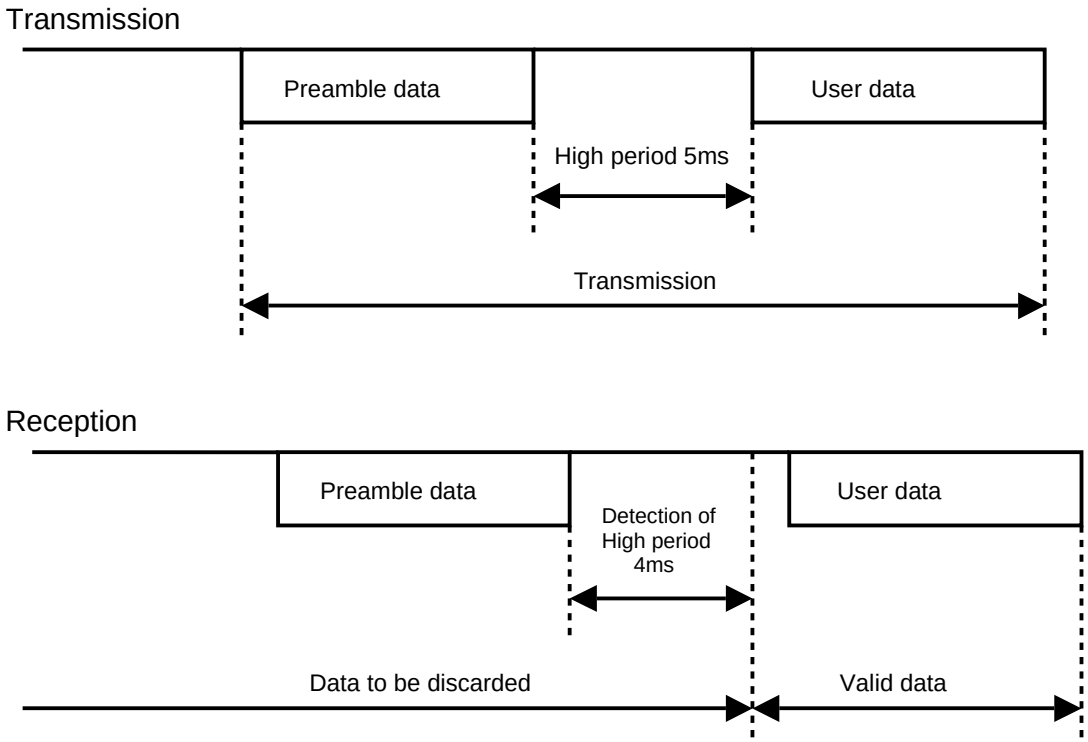
Preamble	ID code					User data						Data-check		Dummy data	
11001100....	CH	01	02	03	04									CC	CC
Repeated 0xCC > 20 ms	1 byte	ID 4bytes				18 bytes						CRC 2bytes		2 bytes	

8.5.2 Data synchronization using UART

With the MU-4 set to the transparent mode, the transmission data input at the DI terminal will be wirelessly transferred as it is, and the data received at DO terminal will be output in positive logic as it is.
The length of continuous 1 or 0 data that can be dealt with the DI and DO terminals is 6 ms or less (28 btis for 4800 bps).

When using UART for wireless transmission, it is important how the start of the data can be detected.

In the figure below, the transmitter transmits 5 ms of High period between the preamble data and the user data (including the ID code) in the data frame.
The receiver detects the High period and knows the start of the user data.
If the receiver cannot detect the High period in the received data, the data needs to be processed as invalid data, such as being discarded.

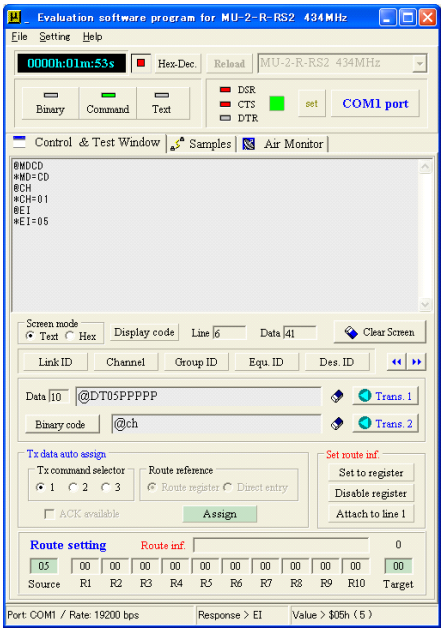


Chapter 9 Miscellaneous

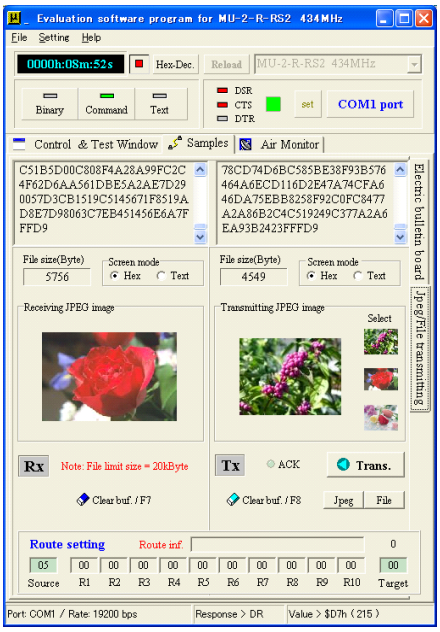
9.1 The MU-4 Evaluation Program

It is convenient to use the dedicated Evaluation Program MU2-ESP for evaluating the MU-4.
Refer to the MU2-ESP manual for details of the evaluation method.
The Evaluation Program can be downloaded from the Circuit Design website.
You can issue all the commands from the control & test window. You can also check the performance of the MU-4 with a communication test where an image is transmitted using one-way communication. Using the air monitor, you can check the field status of the equipment you design. (It is necessary to design your product so that it can be connected to a PC with the RS232C interface.)

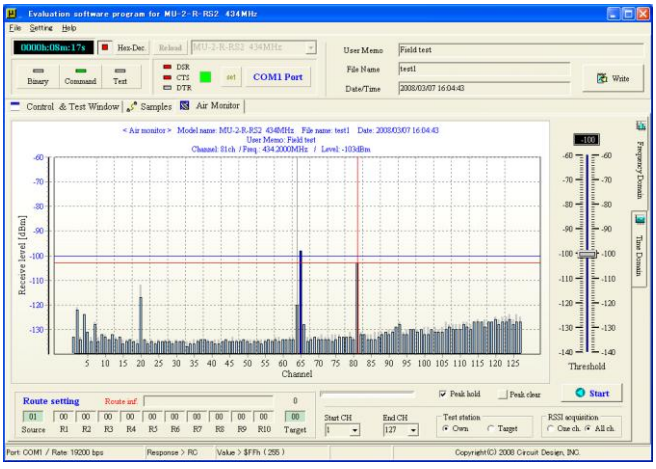
◆Control & test window



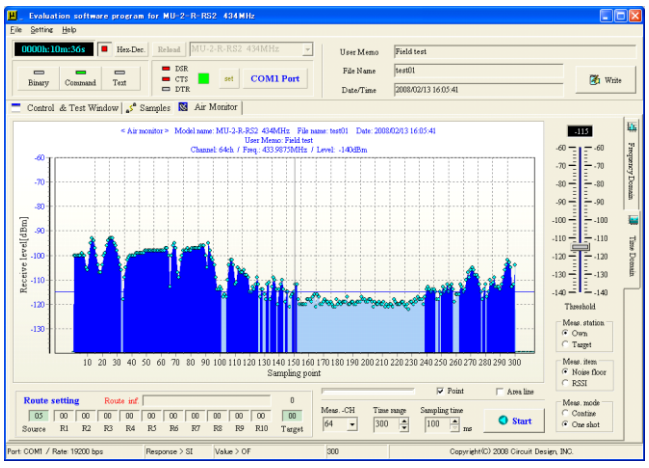
◆JPEG image transmission test



◆ Air monitor (frequency domain)



◆Air monitor (time domain)



Chapter 10 Regulatory Compliance

Regulatory Compliance of the MU-4

EU Declaration of Conformity
Hereby, Circuit Design, Inc. declares that the MU-4 is in compliance with RE Directive (2014/53/EU).
The full text of the EU Declaration of Conformity is available at www.circuitdesign.jp.

UK Declaration of Conformity
Hereby, Circuit Design, Inc. declares that the MU-4 is in compliance with The Radio Equipment Regulations 2017 (S.I. 2017/1206).
The full text of the UK Declaration of Conformity is available at www.circuitdesign.jp.

Cautions related to regulatory compliance when embedding the MU-4

1. Duty cycle
The MU-4 is designed to be used in the EU wide harmonised frequency bands for shor range devices. The transmitting time and downtime of the MU-4 and selection of the frequency channel are controlled by the final product in which the MU-4 is embedded. The final product in which the MU-4 is used must be designed so that the frequency band and duty cycle conform to the radio regulations of the countries where it is to be used.

2. Antenna
The conformity assessment of the MU-4 was performed using Circuit Design's standard antenna ANT-RIG-01 (1/4 lambda lead antenna), so we recommend using the ANT-RIG-01 antenna or an antenna with equivalent characteristics (2.14 dBi or less). For details about our standard antenna, refer to www.circuitdesign.jp or contact us. If you use an antenna other than the recommended antenna, further radio conformity assessment may be required.

3. Supply voltage
The MU-4 should be used within the specified voltage range (3.0 V to 5.0 V).

4. Enclosure
To fulfill the requirements of EMC and safety requirements, the MU-4 should be mounted on the circuit board of the final product and must be enclosed in the case of the final product. No surface of the MU-4 should be exposed.

Conformity assessment of the final product

The manufacturer of the final system needs to conduct full EMC testing in the final configuration and also ensure the final product fulfills the health and safety requirements and is also responsible for the conformity assessment procedures of the final product in accordance with the RE Directive.

Important notice

- Customers are advised to consult with Circuit Design sales representatives before ordering.
  Circuit Design believes the provided information is accurate and reliable. However, Circuit Design reserves the right to make changes to this product without notice.

- Circuit Design products are neither designed nor intended for use in life support applications where malfunction can reasonably be expected to result in significant personal injury to the user. Any use of Circuit Design products in such safety-critical applications is understood to be fully at the risk of the customer and the customer must fully indemnify Circuit Design, Inc for any damages resulting from any improper use.
- As the radio module communicates using electronic radio waves, there are cases where transmission will be temporarily cut off due to the surrounding environment and method of usage. The manufacturer is exempt from all responsibility relating to resulting harm to personnel or equipment and other secondary damage.
- The manufacturer is exempt from all responsibility relating to secondary damage resulting from the operation, performance and reliability of equipment connected to the radio module.

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Cautions

- Do not use the equipment within the vicinity of devices that may malfunction as a result of electronic radio waves from the radio module.
- Communication performance will be affected by the surrounding environment, so communication tests should be carried out before actual use.
- Ensure that the power supply for the radio module is within the specified rating. Short circuits and reverse connections may result in overheating and damage and must be avoided at all costs.
- Ensure that the power supply has been switched off before attempting any wiring work.
- The case is connected to the GND terminal of the internal circuit, so do not make contact between the '+' side of the power supply terminal and the case.
- When batteries are used as the power source, avoid short circuits, recharging, dismantling, and pressure. Failure to observe this caution may result in the outbreak of fire, overheating and damage to the equipment. Remove the batteries when the equipment is not to be used for a long period of time. Failure to observe this caution may result in battery leaks and damage to the equipment.
- Do not use this equipment in vehicles with the windows closed, in locations where it is subject to direct sunlight, or in locations with extremely high humidity.
- The radio module is neither waterproof nor splash proof. Ensure that it is not splashed with soot or water. Do not use the equipment if water or other foreign matter has entered the case.
- Do not drop the radio module or otherwise subject it to strong shocks.
- Do not subject the equipment to condensation (including moving it from cold locations to locations with a significant increase in temperature.)
- Do not use the equipment in locations where it is likely to be affected by acid, alkalis, organic agents or corrosive gas.
- Do not bend or break the antenna. Metallic objects placed in the vicinity of the antenna will have a great effect on communication performance. As far as possible, ensure that the equipment is placed well away from metallic objects.
- The GND for the radio module will also affect communication performance. If possible, ensure that the case GND and the circuit GND are connected to a large GND pattern.

Warnings

- Do not take a part or modify the equipment.
- Do not remove the product label (the label attached to the upper surface of the module.) Using a module from which the label has been removed is prohibited.

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REVISION HISTORY

Version	Date	Description	Remark
1.0	Sept. 2020	The first issue	
2.0	Mar. 2021	4.11 EEPROM readout error & 5.4.8 Information response added	
3.0	Aug. 2021	UKCA added, Correction of erroneous description TR command timing added	
4.0	Jan. 2022	Correction of erroneous description	@TC, @CA, @RC
5.0	Feb. 2026	Description about the standby mode deleted	