Modbus Transparent

920MHz Band Wireless Device (Taiwan)

USERS MANUAL

CONTENTS

■**TRADEMARKS**

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■**Notes**

• We are not responsible for any effect caused by the results of using the products and this manual.
• We are not responsible for any effect caused by operations not described in this manual.
• The specifications of the products and the descriptions in this manual are subject to change without notice.
• A "module" or "wireless module" displayed on the maintenance console indicates a "wireless device".
• "Maintenance console" in this manual indicates "MH920 Console International" manufactured by Oki Electric Industry Co., Ltd.
• Do not disconnect the mini USB cable or turn off the power supply of a wireless device while connecting the maintenance console and the device, or the settings in writing (updating or setting firmware) may be destroyed.

1. INTRODUCTION

The wireless devices configure a large-scale and highly reliable wireless multihop network system, which operates in the 920 MHz frequency band and complies with IEEE802.15.4g. The system can be used for various services such as BEMS, Smart Metering, and M2M. There are two types of wireless devices: parent devices and wireless devices.

1.1 FEATURES

The wireless network system allows to collect data wirelessly from data acquisition devices and remote I/Os using Modbus protocol. A wireless device (parent) communicates with the data acquisition device using Modbus/TCP protocol and with wireless devices (child) using Modbus-RTU protocol. The parent device converts between Modbus-RTU and Modbus/TCP protocols.

1.1.1 BASIC CONFIGURATION

"Figure 1.1 System configuration example" shows a system where a PC side as Modbus/Master communicates with a child device via a 920 MHz band wireless device using Modbus/TCP and RTU protocol, and also communicates with slave devices in multi drop connection (RS-485).
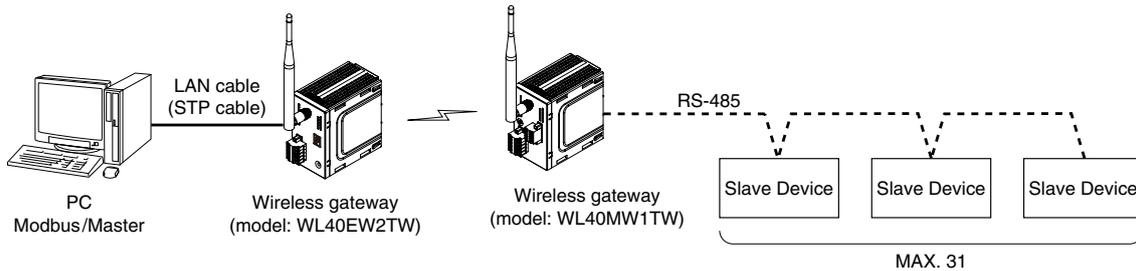
Figure 1.1 System configuration example

1.1.2 CONFIGURATION INCLUDING LOW-SPEED MOVING DEVICES

A data acquisition device can collect data wirelessly from remote I/Os moving at low speed (4 km/h or less). The configuration consists of a parent device, repeaters and child devices. Only the child devices move and do not function as repeaters.

In this configuration, it is possible to manage the devices moving at low speed within a specific range and collect data from them through radio communication.
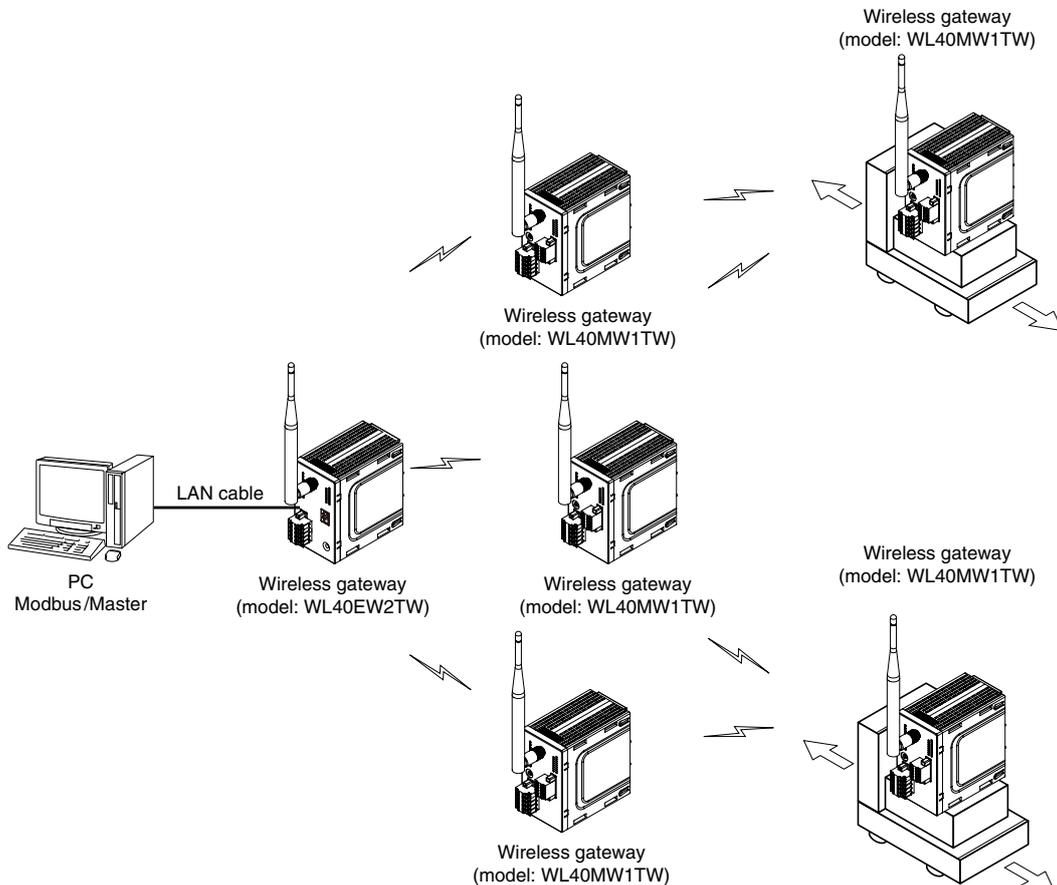
Figure 1.2 System configuration example including low-speed moving device

1.2 SPECIFICATIONS

The table below shows the specifications of the wireless network system.

[Table 1.1] Specifications of wireless network system

ITEM		SPECIFICATIONS
Wireless system	Baud rate	Max. 100 kbps
	Effective rate	10 kbps
	Number of child devices	Max. 100 per parent device
	Number of hops	Max. 16
	Number of child nodes	25 or 15

The table below shows the specifications of the wireless communication module of the wireless devices.

[Table 1.2] Specifications of wireless communication module

ITEM		SPECIFICATIONS
Wireless interface	Agency certification	NCC
	Frequency	920 MHz band (920.2 – 924.8 MHz)
	Bandwidth	400 kHz
	Max. transmission power	20 mW
	Baud rate	Max. 100 kbps
	Max. packet size	2048 bytes
	Max. transmission distance	Approx. 1 km (line of sight) Note 1: The distance may vary depending on the installation environment. Note 2: Use of a coaxial cable for antenna extension shortens the distance due to cable loss.
	Modulation	GFSK
	Receive sensitivity	-90 dBm or less (PER = 10%)

1.3 PRODUCT LINEUP

■ PARENT DEVICE

[Table 1.3] Parent device

MODEL	FEATURES
WL40EW2TW	Works as a gateway, converting between Modbus-RTU and Modbus/TCP (Ethernet) protocols. Selectable between sleeve and rooftop antennas

■ CHILD DEVICE

[Table 1.4] Child device

MODEL	FEATURES
WL40MW1TW	Wireless gateway Selectable between sleeve and rooftop antennas

2. FLOW UNTIL START OF SYSTEM OPERATION

Below is the flow until start of the system operation.

Confirm each step in the flow and take necessary actions such as designing the network configuration, setting wireless devices, etc.

1) EXAMINING WIRELESS NETWORK CONFIGURATION
2) SELECTING DEVICES
3) PREPARING MAINTENANCE CONSOLE
4) PRELIMINARY MEASUREMENT OF RADIO WAVE ENVIRONMENT
5) EXAMINING PARAMETERS OF WIRELESS DEVICES
6) SETTING WIRELESS DEVICES
7) INSTALLING WIRELESS DEVICES
8) MEASUREMENT OF RADIO WAVE ENVIRONMENT

3. EXAMINING WIRELESS NETWORK CONFIGURATION

3.1 MULTIHOP NETWORK

3.1.1 NETWORK PARTICIPATION AND ROUTE CONFIGURATION

A wireless multihop network can be configured with a parent device and multiple child devices.

Each child device obtains authentication from the parent device to join the network after startup, and communicates using its IPv6 address.

The IPv6 address is assigned automatically using the prefix set to the parent device and short addresses set individually to the parent device and each child device.

■ **UPSREAM ROUTE**

1) A child device collects information on the number of hops and the network quality (packet error rate) from adjacent parent and child devices, and decides a preferential parent as a connection destination from a list of parent candidates selected from the adjacent devices.
2) Based on the information, the upstream network route of the child device is generated.

■ **DOWNSTREAM ROUTE**

1) The parent device registers the route transmitted from the child device in its route information table.
2) With this table, the parent device automatically generates the downstream network route (source routing) to the child device.
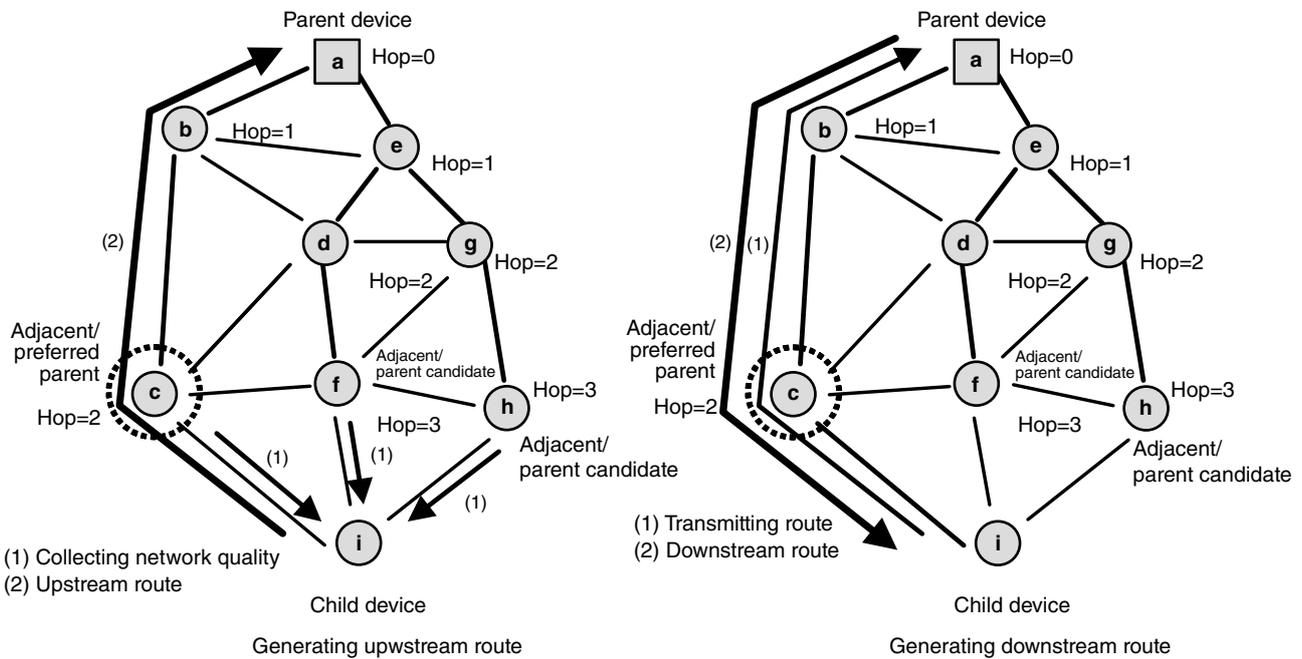
Figure 3.1 Wireless network

3.2 CONFIRMING COMPONENTS IN INSTALLATION ENVIRONMENT

Confirm the installation locations and the wiring destinations of a data acquisition device and remote I/Os in the installation environment of wireless devices.

3.3 CONFIRMING WIRELESS SECTIONS

Determine sections to be used for wireless communications in the installation environment.

Since a parent device is always connected to a data acquisition device, confirm also the connection of the parent device and remote I/O child devices.

4. SELECTING DEVICES

Select wireless devices and accessories necessary to configure the network based on the following criteria.

4.1 WIRELESS DEVICE

■ PARENT DEVICE: WL40EW2TW

The wireless I/O WL40TW series WL40EW2TW connects with an upper device (e.g. data acquisition device) via TCP/IP to collect data from remote I/Os connected to wireless child devices.
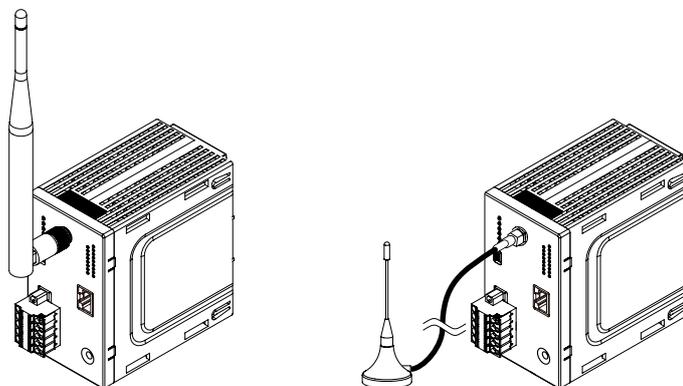
Figure 4.1 Parent device

[Table 4.1] Specifications of parent device

ITEM	SPECIFICATIONS
Power input	24V DC or 12V DC
Current consumption	24V DC: ≤ 90mA 12V DC: ≤ 170mA
Operating temperature	-20 to +60°C (-4 to +140°F)
Mounting	DIN rail
Dimensions	105 mm × 60 mm × 107 mm (4.13 × 2.36 × 4.21 inch) (excluding antenna and protrusions)

■ CHILD DEVICE: WL40MW1TW

The wireless I/O WL40TW series WL40MW1TW works as a gateway to output data received wirelessly to devices connected by wire.
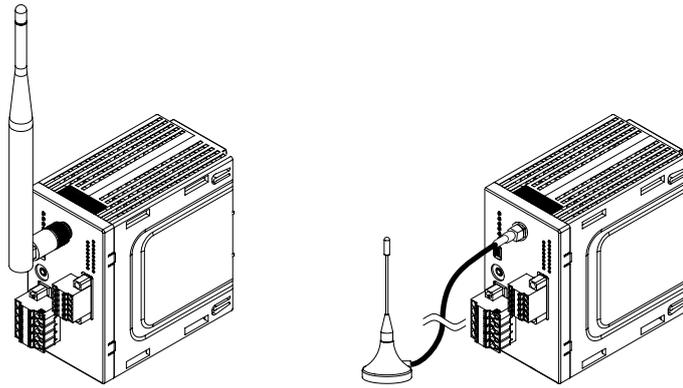
Figure 4.2 Child device

[Table 4.2] Specifications of child device

ITEM	SPECIFICATIONS
Power input	24V DC or 12V DC
Current consumption	24V DC: ≤ 70mA 12V DC: ≤ 130mA
Operating temperature	-20 to +60°C (-4 to +140°F)
Mounting	DIN rail
Dimensions	105 mm × 60 mm × 107 mm (4.13 × 2.36 × 4.21 inch) (excluding antenna and protrusions)

4.2　ANTENNA

■ ANTENNAS FOR WL40TW SERIES

Following two antennas are available for the wireless I/O WL40TW series.

Select either antenna according to the usage scenes and their respective characteristics.

Figure 4.3 Sleeve antenna　　　　　　　　　　　　　　Figure 4.4 Rooftop antenna

• Sleeve antenna

An indoor-use antenna to attach to a wireless device. Tilting the antenna up to 90° deflects radio wave.

• Rooftop antenna

An antenna with a 2.5-m coaxial cable to install away from a wireless device.

This antenna is waterproof and suited for outdoor use as well.

To fully exhibit the characteristics of the monopole rooftop antenna, a ground plane equivalent to the electric ground is needed.

Attach its magnet base on a metal plate (recommended dimensions: 500 mm × 500 mm or more).

The gain of the rooftop antenna is less than that of the sleeve antenna for approximately 2.5 dB.

However the rooftop antenna has the advantage that it can be installed in a high location, which is effective for the reachability of radio wave.

The specifications of the antennas are as shown in the table below.

[Table 4.3] Specifications of antennas for wireless devices

ITEM	SPECIFICATIONS	
Type	Sleeve antenna	Rooftop antenna
Installation environment	Indoor	Outdoor
Cable length	–	2.5 m
Antenna type	Dipole	Monopole
Gain	3 dBi max. (*)	2 dBi max. (*)
Waterproof property	Non-waterproof	Waterproof (IPX6)
Directionality	Non-directional in horizontal plane	Non-directional in horizontal plane
Dimensions	195 mm (7.68 inch) (including connector)	80 mm (3.15 inch) (including base)

* The performance of the antennas may be affected by the installation environment.

4.3　COAXIAL CABLE

A coaxial cable is available for extension of the rooftop antenna.

The table below shows specifications of the coaxial cable (Oki Electric Industry Co., Ltd.).

[Table 4.4] Specifications of coaxial cable

ITEM	SPECIFICATIONS
Type	Extension cable for rooftop antenna
Cable length	7.5 m (including connector)
Frequency	0 – 6 GHz
Impedance	50 Ω (nominal)
Cable loss	Approx. 3.1 dB in 800 MHz band Approx. 3.5 dB in 1000 MHz band
Connector	SMA, non-waterproof *
Cable	RG58

* The connector is not waterproof. For its metal material, apply insulation treatment (e.g. taping).

5. PREPARING MAINTENANCE CONSOLE

5.1 DOWNLOADING MAINTENANCE CONSOLE

To perform maintenance of wireless devices, please install the "MH920 Console International" (hereafter referred to as 'maintenance console') software in your PC.

The maintenance console is downloadable at our web site.

Note: The maintenance console software of Oki Electric Industry Co., Ltd. is employed since the wireless devices incorporate the wireless communication modules manufactured by Oki.

5.1.1 APPLICABLE VERSION

See below for the latest version of the maintenance console applicable to the wireless communication modules.

[Table 5.1] Maintenance console version

Communication module version	Maintenance console version
Ver f4.3.0	Ver 4.32 or later

5.2 INSTALLING & UNINSTALLING MAINTENANCE CONSOLE AND USB DRIVER

The following PC performance is required for adequate operation of the maintenance console.

Check the operating environment of the PC before installation.

■ **HARDWARE REQUIREMENTS**

[Table 5.2] Hardware requirements

ITEM	REQUIREMENTS
CPU	Core Duo 1 GHz equivalent or above
Memory	1 GB or more
HDD	100 MB minimum free space
Interface	USB *

* USB version 1.1 or 2.0.

■ **SOFTWARE REQUIREMENTS**

[Table 5.3] Software requirements

ITEM	REQUIREMENTS
OS	Windows 7 Professional SP1 (32-bit / 64-bit) Windows 8.1 (64-bit) Windows 10 (64-bit)
Runtime	Microsoft .NET Framework version 4.0

5.2.1 INSTALLING MAINTENANCE CONSOLE

Install the maintenance console according to the following procedure.

1) Extract the downloaded files of the maintenance console.
2) Execute "mh920consoleInternational.msi" in the extracted files and start the setup wizard.
   When the "Setup Wizard" screen appears, click [Next].
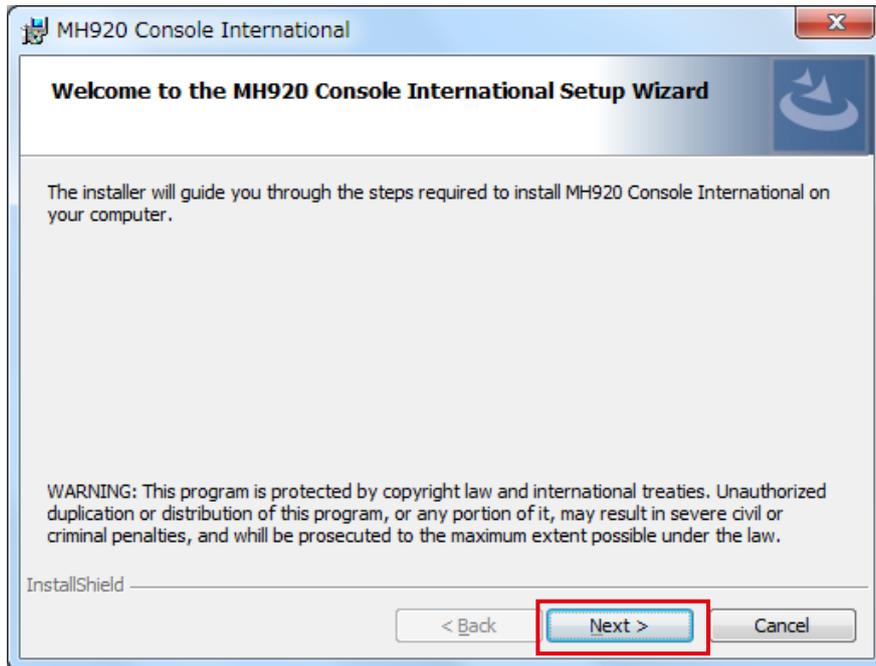
Figure 5.1 Setup wizard

Note: When "Microsoft .NET Framework 4" is not installed, a message box that requires the installation appears.
After installing "Microsoft .NET Framework 4", execute "mh920consoleInternational.msi" again.

3) After scrolling down and reading the entire "License Agreement," check [I accept the terms in the license agreement], then click [Next].

Figure 5.2 License agreement

4) When the "Destination Folder" dialog box appears, specify an installation folder and click [Next].
The default location of the installation folder is as follows depending on the operating systems of the PC.
- For 32-bit OS   C:\Program Files\OKI\MH920 Console International\
- For 64-bit OS   C:\Program Files (x86)\OKI\MH920 Console International\
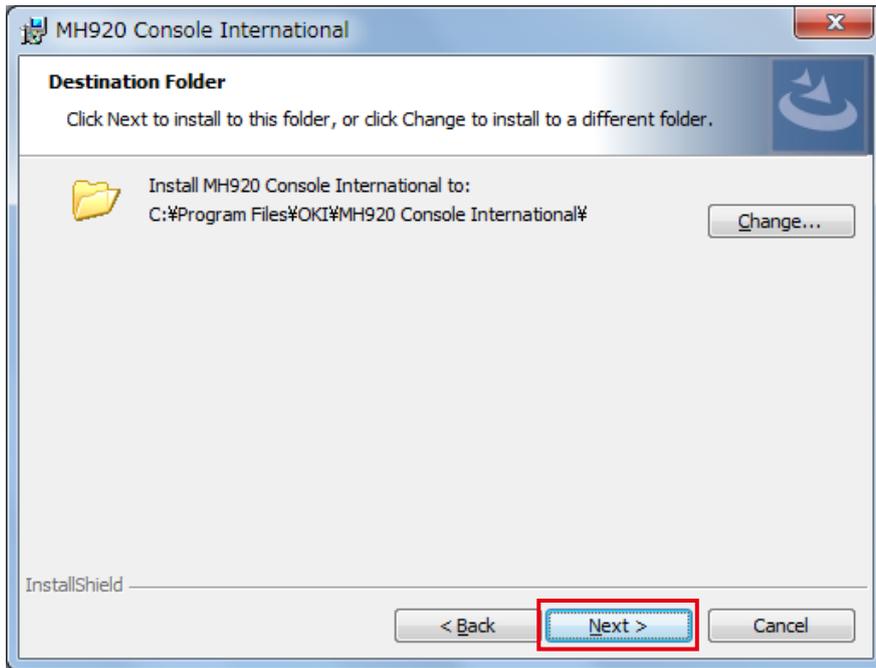
Figure 5.3 "Destination Folder" dialog box (32-bit OS)
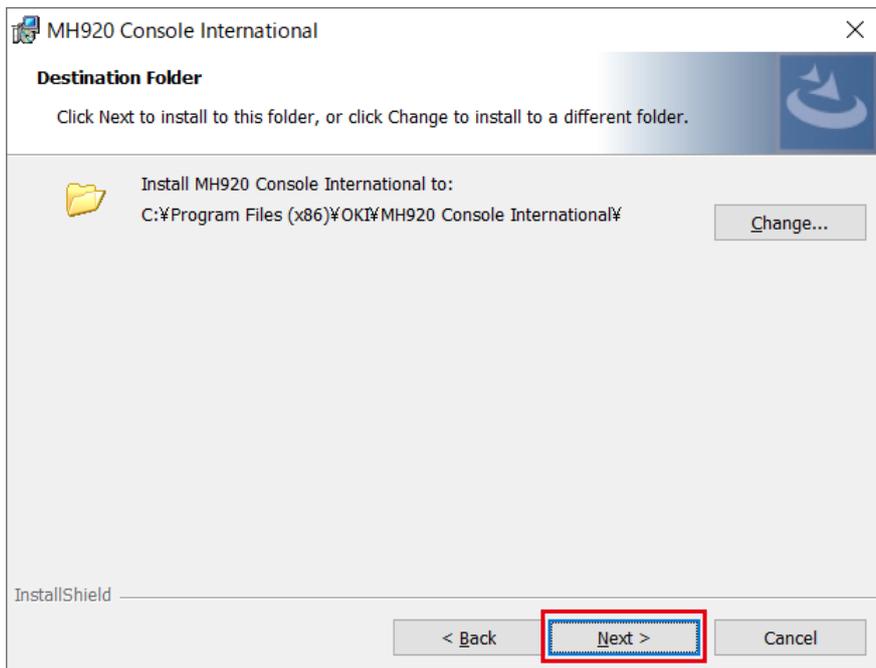
Figure 5.4 "Destination Folder" dialog box (64-bit OS)

5) When the "Set Country" dialog box appears, select "Taiwan (TW)," and click [Next].
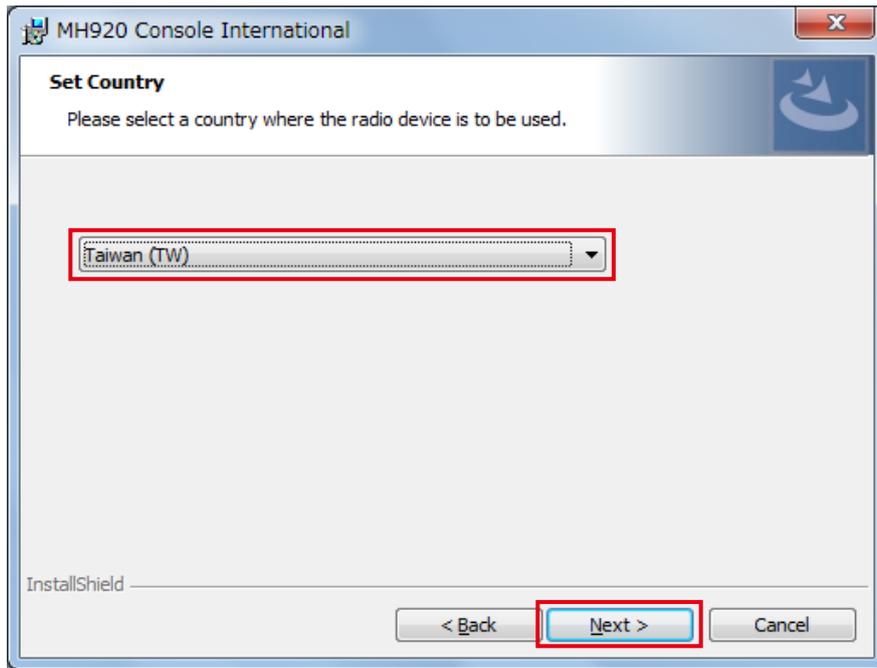
Figure 5.5 "Set Country" dialog box

6) When the "Ready to Install the Program" dialog box appears, select "Everyone," and click [Install].
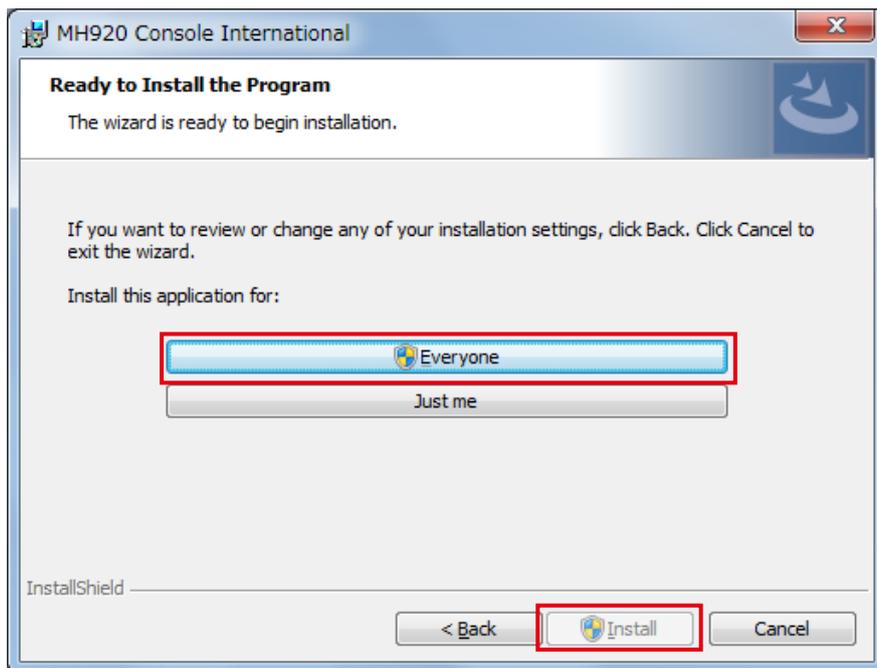
Figure 5.6 "Ready to Install the Program" dialog box

Note: When "User Account Control" dialog box appears to confirm whether to allow the change in Windows 7, click [Yes].

7) After the "InstallShield Wizard Completed" message box appears, click [Finish] to finish the installation.
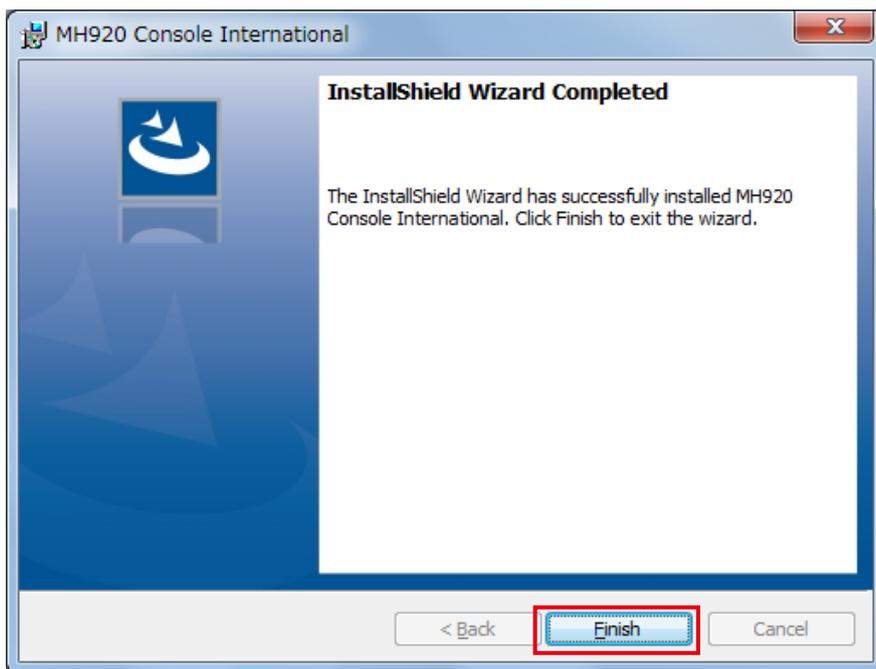
Figure 5.7 "Installation Complete" message box

5.2.2 INSTALLING USB DRIVER

A USB driver is required when connecting a wireless device to the PC.

Install the USB driver according to the following procedure.

1) Connect the wireless device with the PC via a mini USB cable.
2) Turn on the power of the wireless device.
3) After a while, a message box appears on the PC stating that the driver of the wireless device cannot be found.
    If the driver installation dialog box appears, cancel without installing at this time.

After steps 1) to 3), take steps 4), 5) and 6) if the operating system of the PC is either Windows 7 or Windows 8.1.

For Windows 10, take steps 7), 8) and 9).

• Windows 7 or Windows 8.1
4) Select "Control Panel" from the start menu.
5) Select "Device Manager" from the list and expand "Other devices".
6) Right-click "USB CDC Serial port" to display a menu and select "Properties".
    Then proceed to step 10).
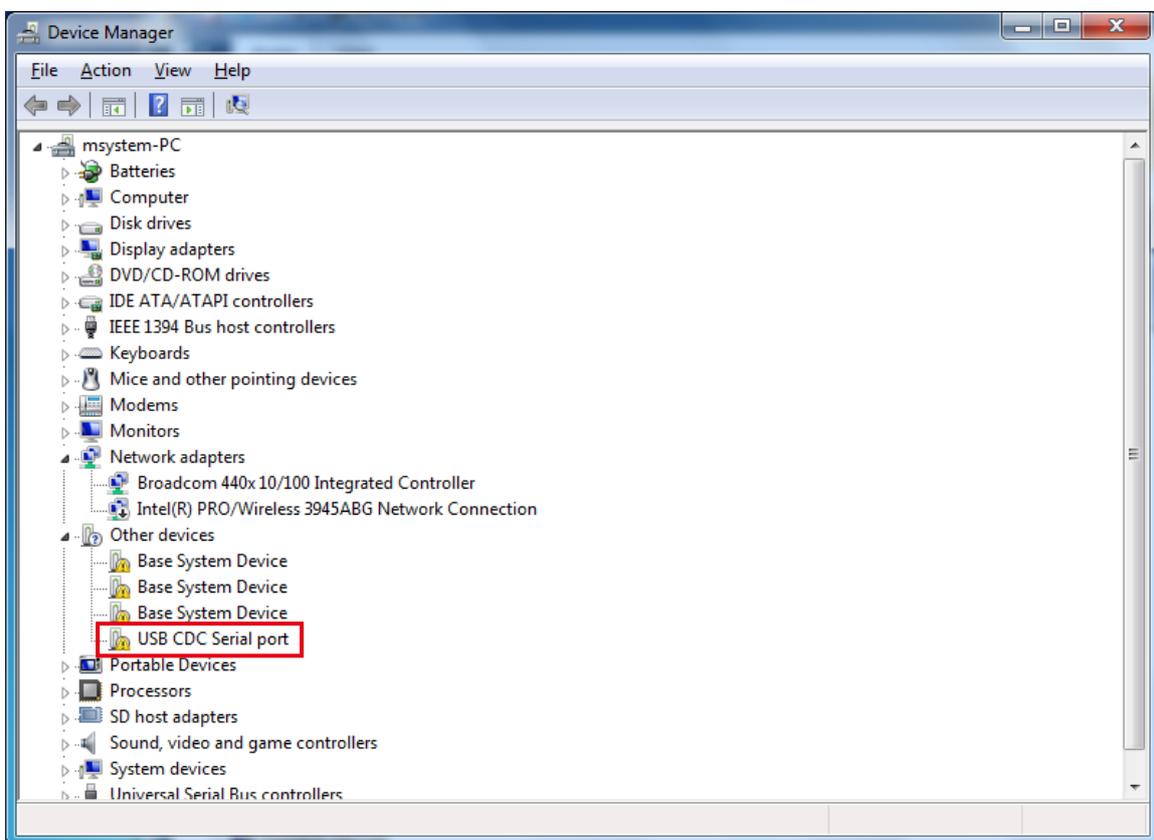
Figure 5.8 Device manager (Windows 7 or Windows 8.1)

• Windows 10
7) Right-click the start button and select "Control Panel".
8) Select "Device Manager" from the list and expand "Ports (COM & LPT)".
9) Right-click "USB Serial Device (COM x)" to display a menu and select "Update Driver Software".
    Then proceed to step 11).
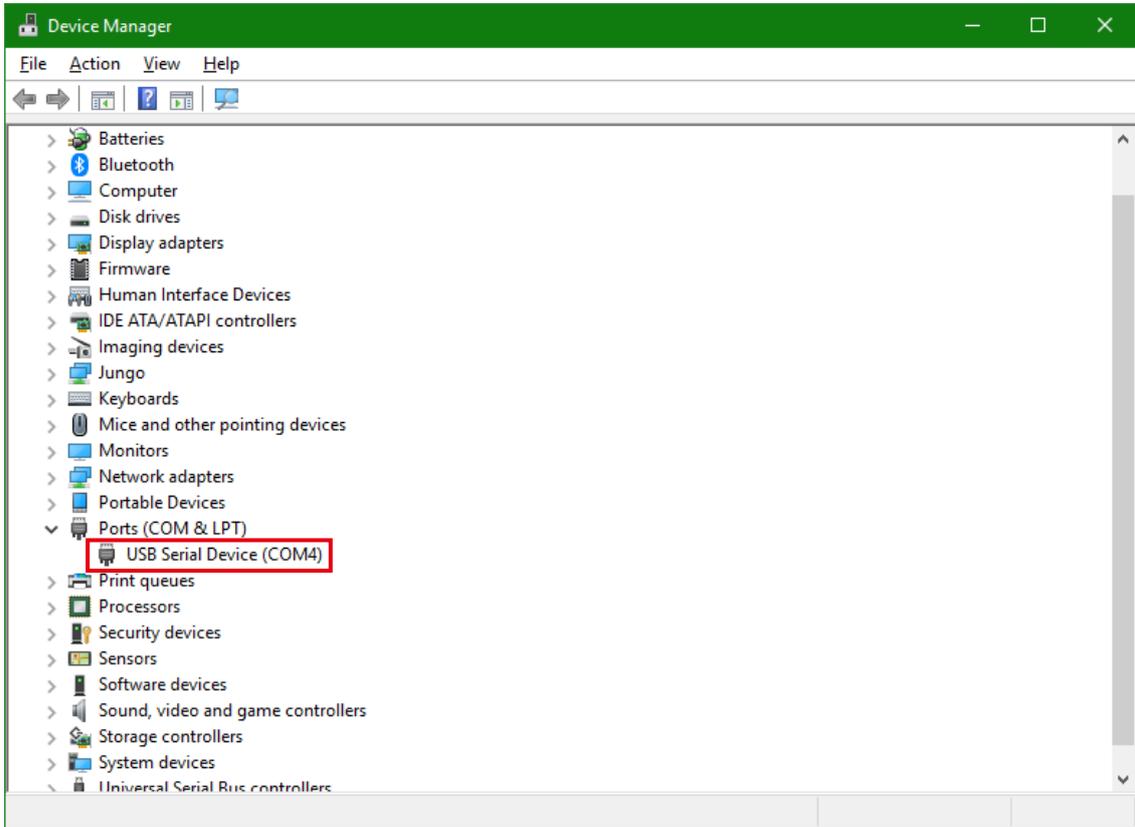
Figure 5.9 Device manager (Windows 10)

10) When the "USB CDC Serial port Properties" dialog box appears, click [Update Driver] to activate the "Update Driver Software" wizard.
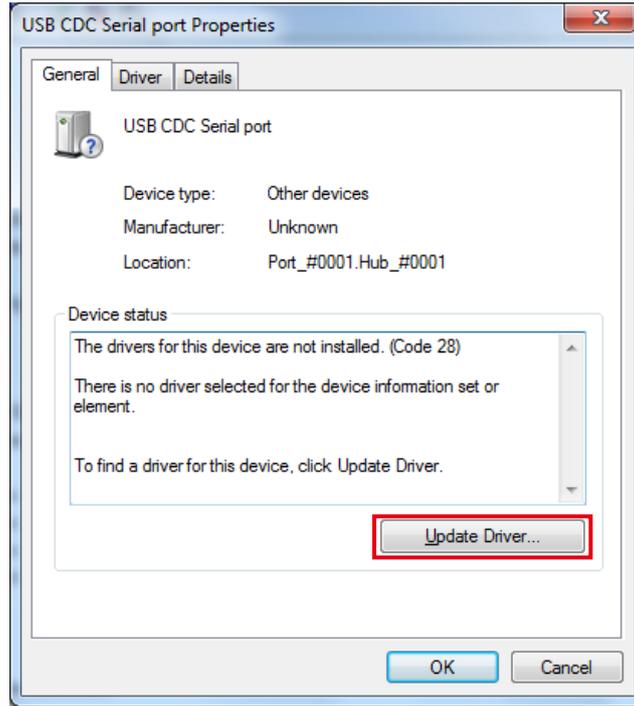
Figure 5.10 USB CDC serial port properties

11) When the "Update Driver Software" dialog box appears, select "Browse my computer for driver software".
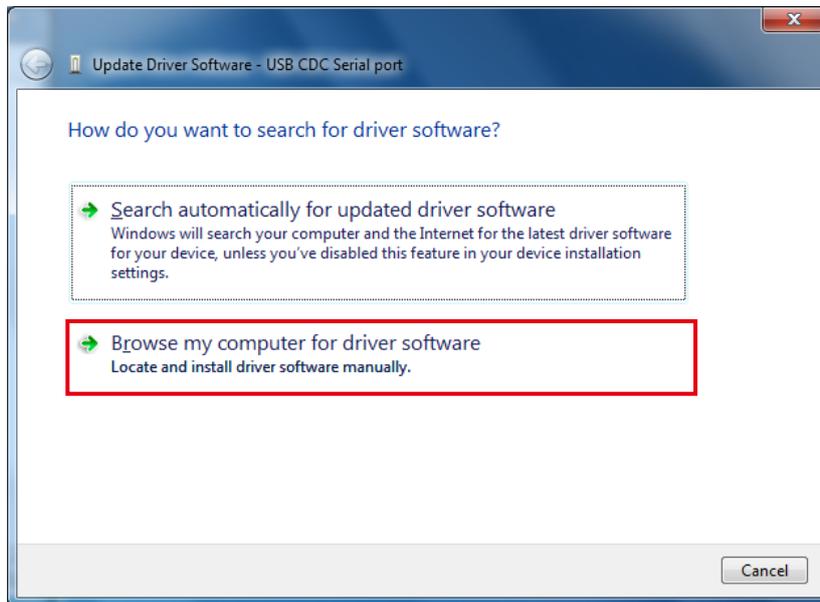
Figure 5.11 Search for driver software

12) On the "Update Driver Software" dialog box, click [Browse], select the installation folder for the maintenance console, and click [Next].
The default location of the installation folder depends on the operating systems of the destination PC.

- For 32-bit OS   C:\Program Files\OKI\MH920 Console International\USB_Driver

- For 64-bit OS   C:\Program Files (x86)\OKI\MH920 Console International\USB_Driver
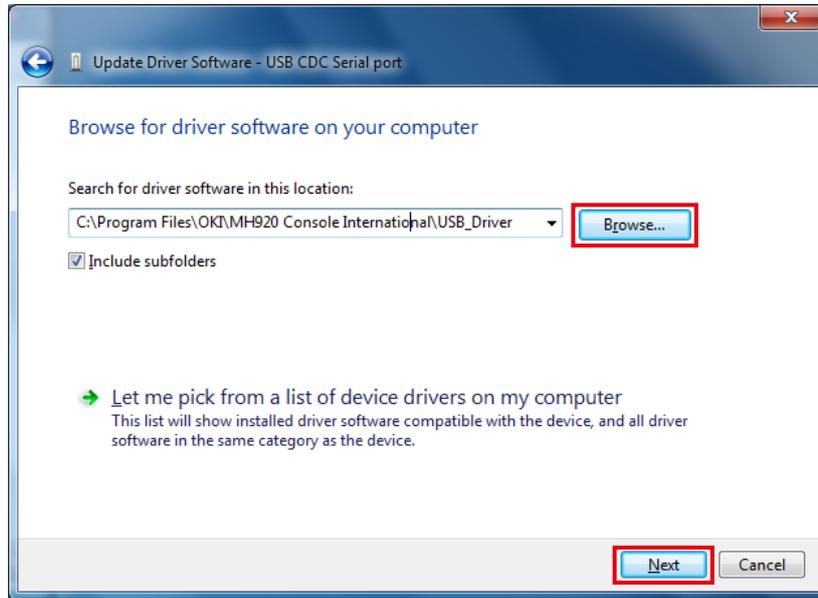
Figure 5.12 "Update Driver Software" dialog box (32-bit OS)
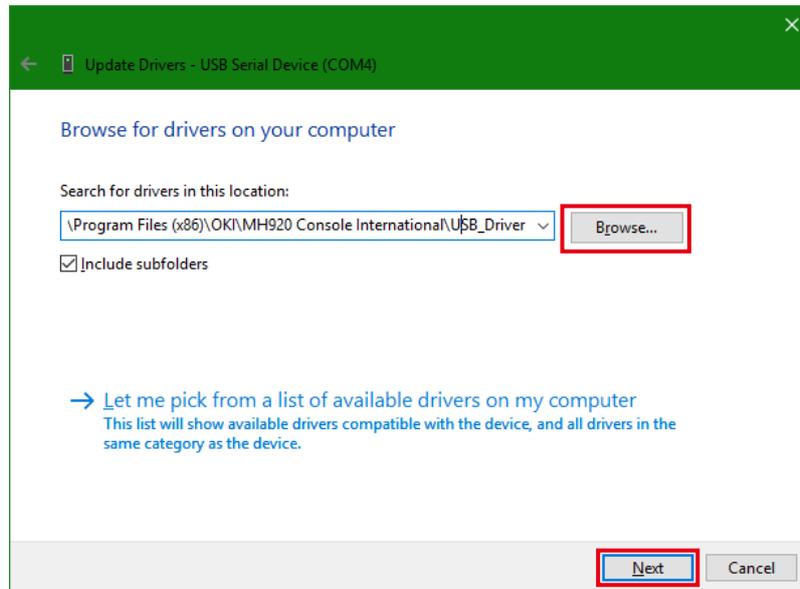
Figure 5.13 "Update Driver Software" dialog box (64-bit OS)

13) When a security warning appears, select "Install this driver software anyway" to continue the installation.
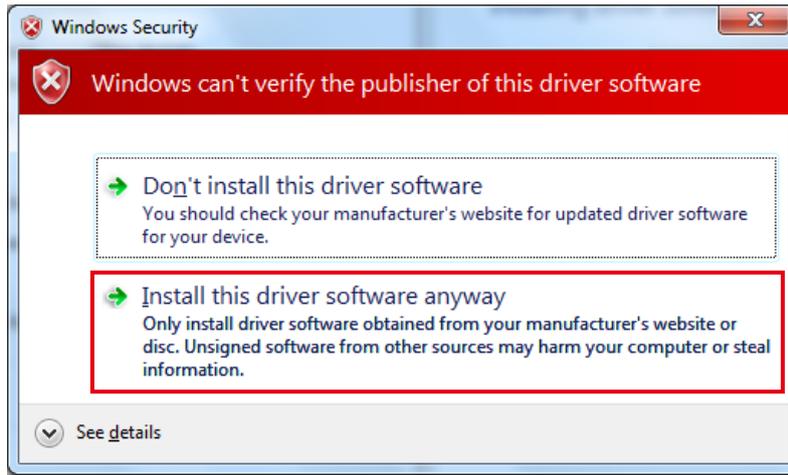
Figure 5.14 Windows Security

14) "Installing driver", then "Installation completed" messages appear in order.
15) Confirm that the driver has been successfully installed on the "Update Driver Software" dialog box, and click [Close].
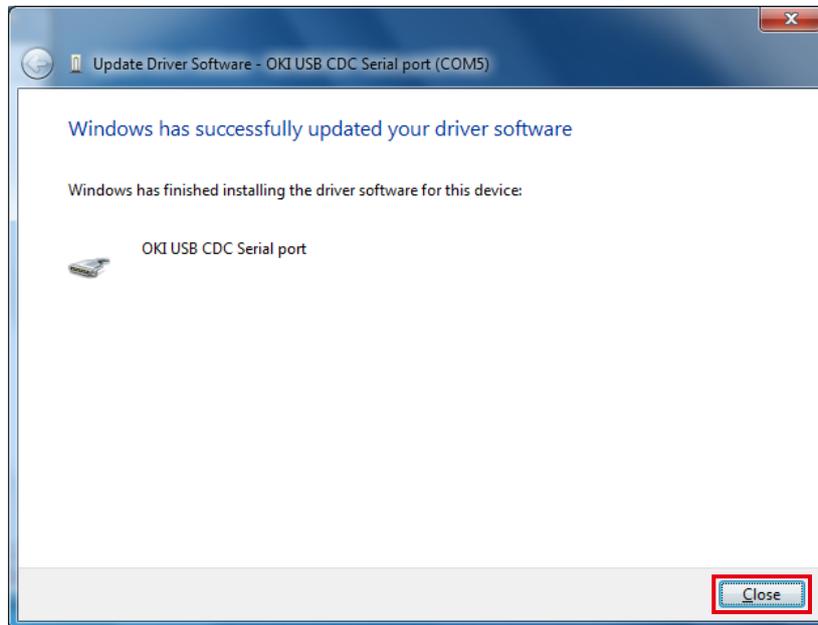
Figure 5.15 "Update Driver Software" dialog box

16) Confirm that the port of "OKI USB CDC Serial port" is displayed in the "Ports (COM & LPT)" column on the Device Manager screen.
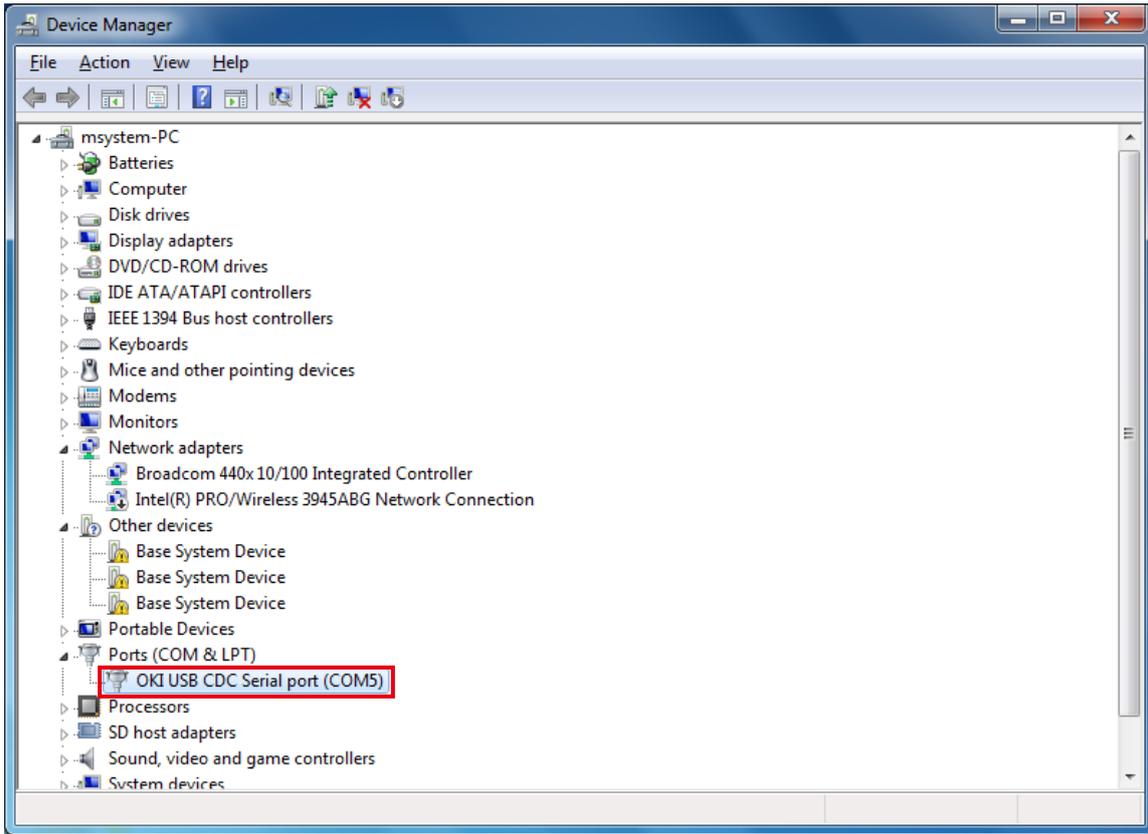
Figure 5.16 Device Manager

Note: Remember this COM port number to be used in COM port setting on the maintenance console.
Figure 5.16 shows an example where the port of "OKI USB CDC Serial port" is COM5.

The USB driver installation is now complete.

5.2.3 UNINSTALLING PROGRAM

Open Control Panel > Programs - Uninstall (for Windows 7).

Select "Microsoft .NET Framework 4" and "MH920 Console International" from the program list and click [Uninstall].

5.3 STARTING MAINTENANCE CONSOLE

Start the maintenance console according to the following procedure.

1) Double-click the shortcut "MH920 Console International" on the desktop to start the maintenance console.

Figure 5.17 Shortcut of "MH920 Console International"

2) The following main screen appears.
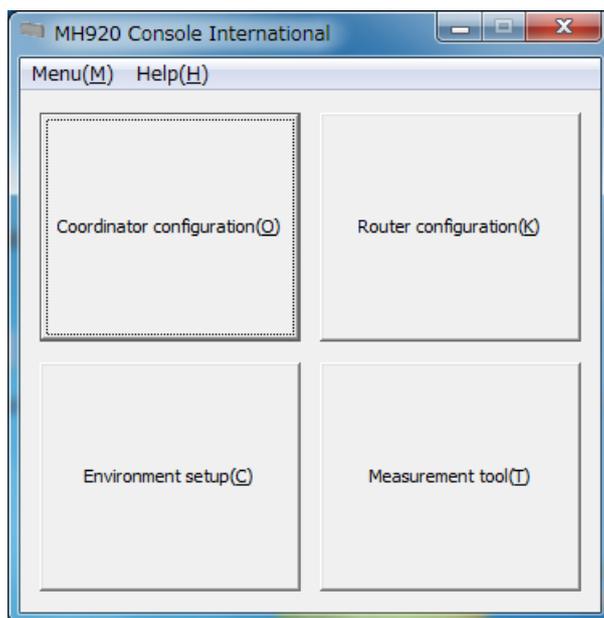
Figure 5.18 Maintenance Console Main Screen

5.3.1 ENVIRONMENT SETUP

This section explains items to be set from "Environment setup" on the main screen of the maintenance console.

Before setting, make sure that the power of the wireless device is turned on and the device is correctly connected to the PC with the maintenance console via a mini USB cable.

5.3.1.1 COM PORT

Set a COM port through which the maintenance console communicates with the wireless device.
1) Click the pull-down button in the "COM port" column to show the COM port list.
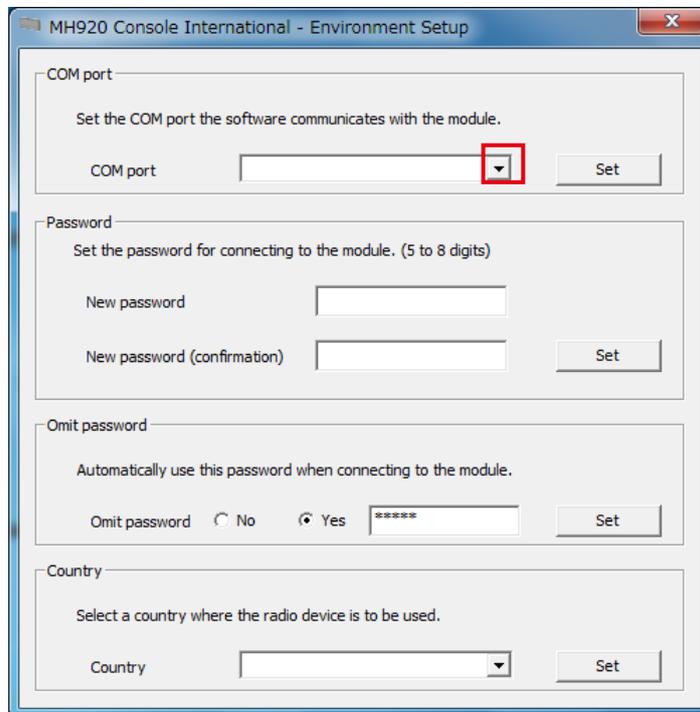
Figure 5.19 COM port setting

2) Select the COM port confirmed in step 16) in "5.2.2. INSTALLING USB DRIVER," and click [Set].
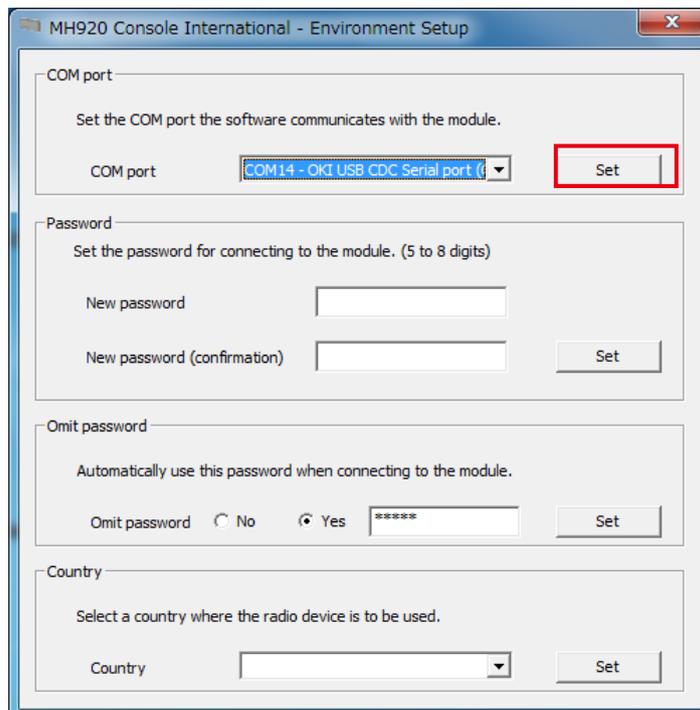
Figure 5.20 Setting COM port

3) A message box appears if the COM port has been changed correctly. Click [OK].

5.3.1.2 PASSWORD

Set a password required for connecting to the wireless device.

1) Enter a password in the "New password" field and enter the same in the "New password (confirmation)" field.
   Refer to "7. EXAMINING PARAMETERS OF WIRELESS DEVICES" on page 53 for the details.
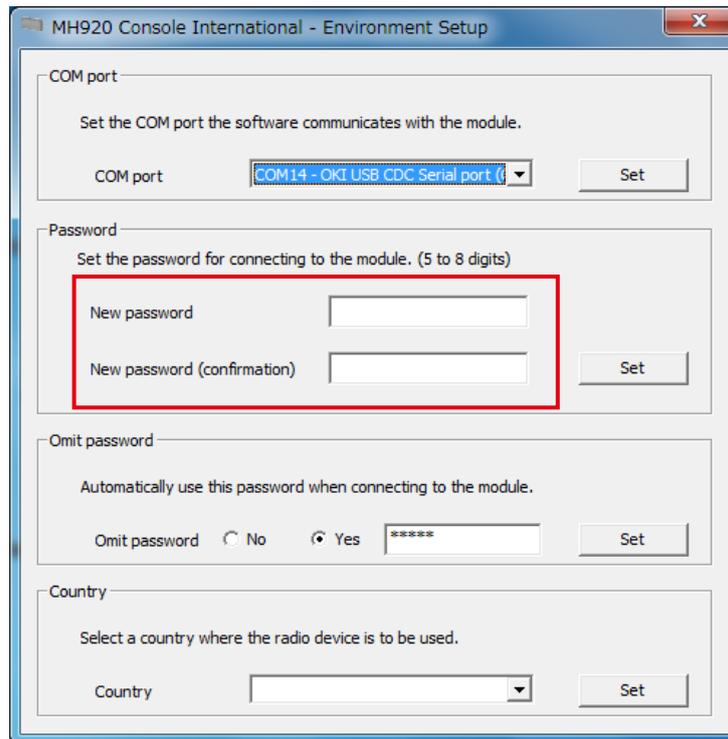
Figure 5.21 Password setting

2) Click [Set] button.
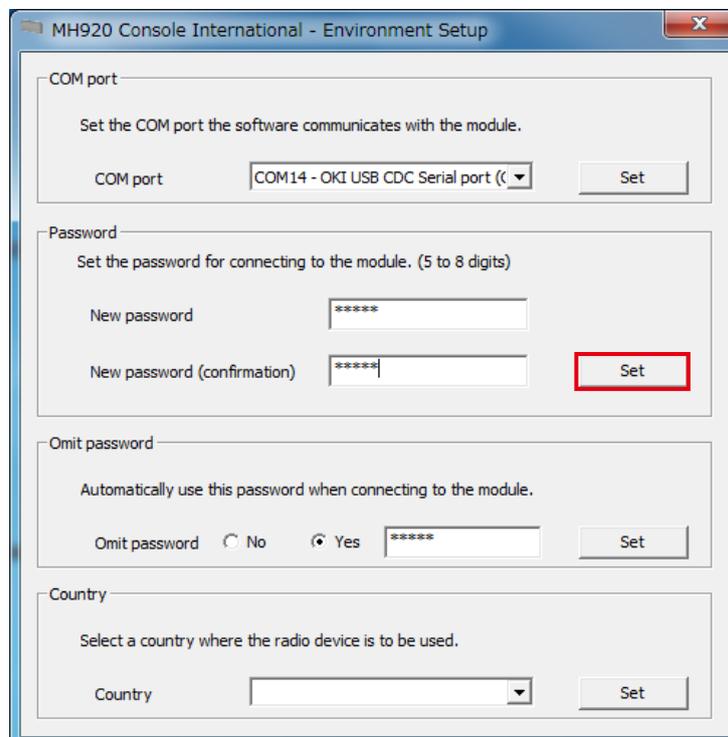
Figure 5.22 password setting

3) If "Omit password" is set to 'No' in "Environment setup", the password is required to connect to a wireless device.
    Enter the password and click [Connect].
4) When the following message appears, click [OK].
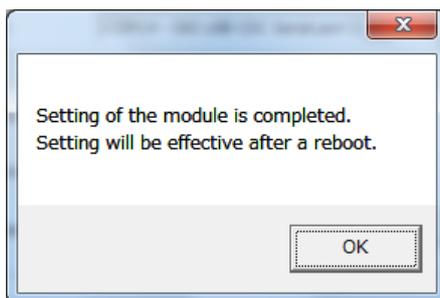
Figure 5.23 Password setting completion message

5.3.1.3 OMITTING PASSWORD

Whether to omit password entry when connecting to a wireless device from the maintenance console can be set.

1) Set a password and "Omit password."
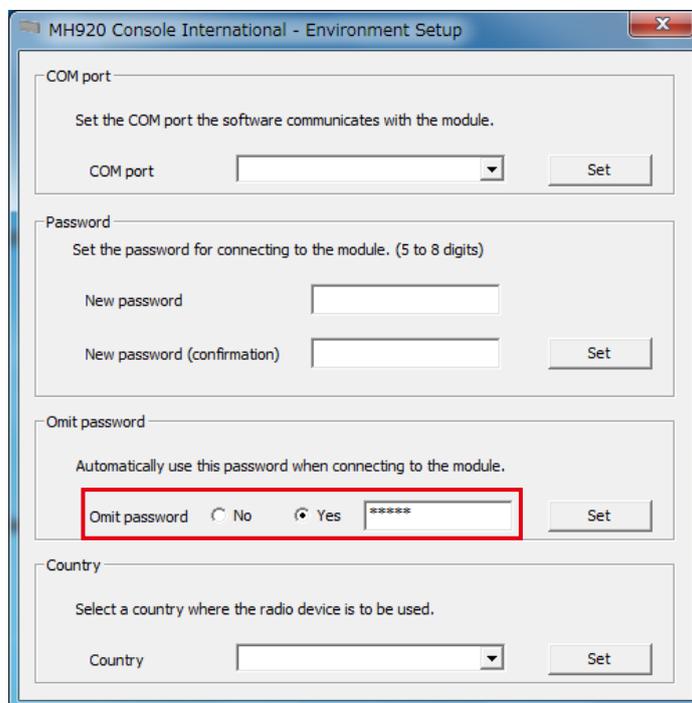
Figure 5.24 "Omit password" setting

[Table 5.4] "Omit password" setting items

ITEM	SETTING VALUE	EXPLANATIONS
Omit password	No / Yes	Check 'No' to enter a password every time connecting to a wireless device. Check 'Yes' not to enter a password every time connecting to a wireless device. The default password is 'mh920'.
Password	5 – 8 one-byte alphanumeric characters	Enter a common password for wireless devices. The input field is enabled with 'yes' checked.

2) Click [Set].
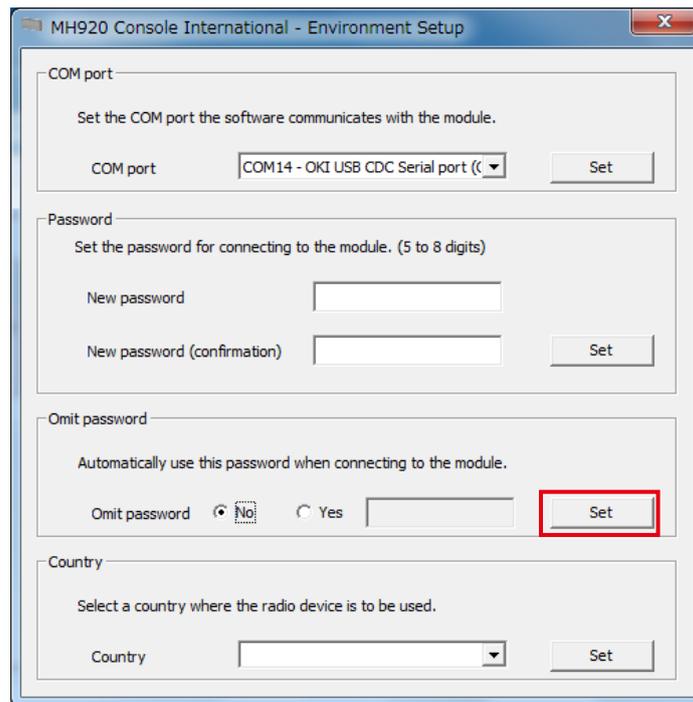
Figure 5.25 "Omit password" setting

3) A message box appears if the "Omit password" setting has been changed correctly.
Click [OK].

5.3.1.4 COUNTRY SETTING

The country where the Maintenance Console is started and used is set.

1) Click the pull-down button in the "Country" column to show the country list.
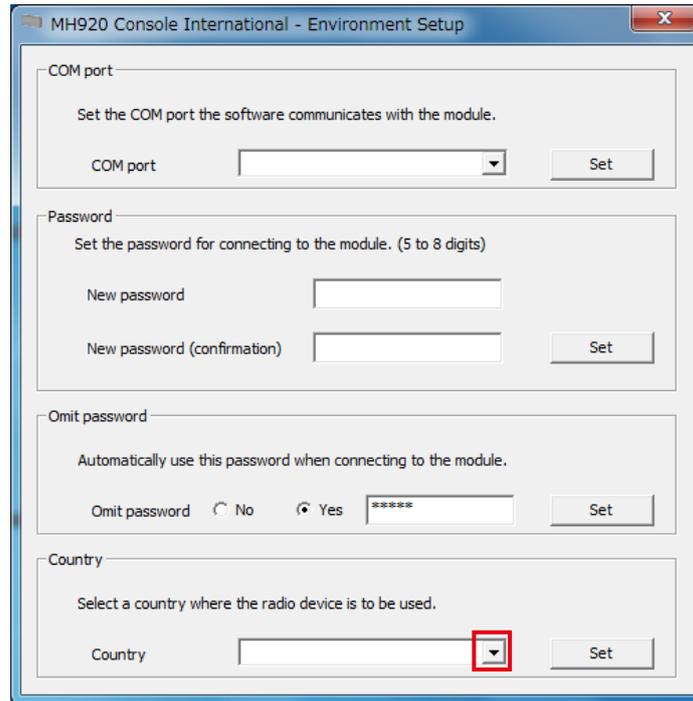
Figure 5.26 "Country" setting

2) Select [Taiwan(TW)] from the list, and click [Set].
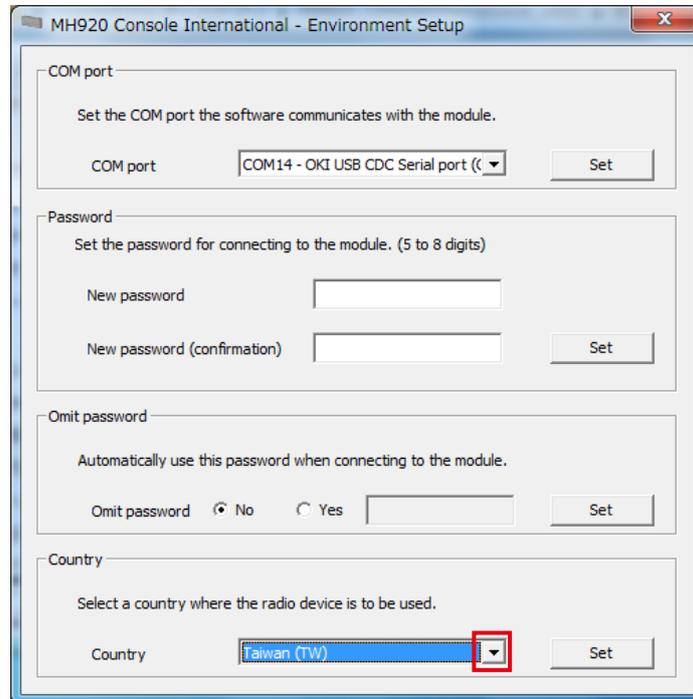
Figure 5.27 "Country" setting

2) The country setting has been applied and setting completion messages appear. Click [OK] on each message.

Figure 5.28 Country setting completion message
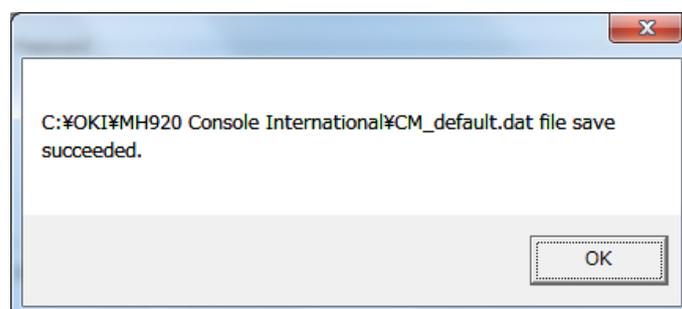
Figure 5.29 Country setting completion message
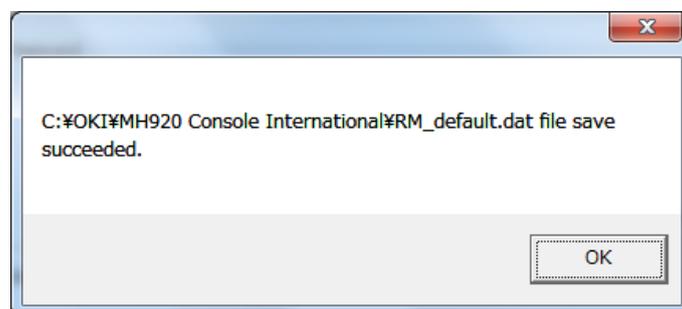
Figure 5.30 Country setting completion message

5.4 OTHER SETTINGS

5.4.1 COORDINATOR CONFIGURATION

Not used.
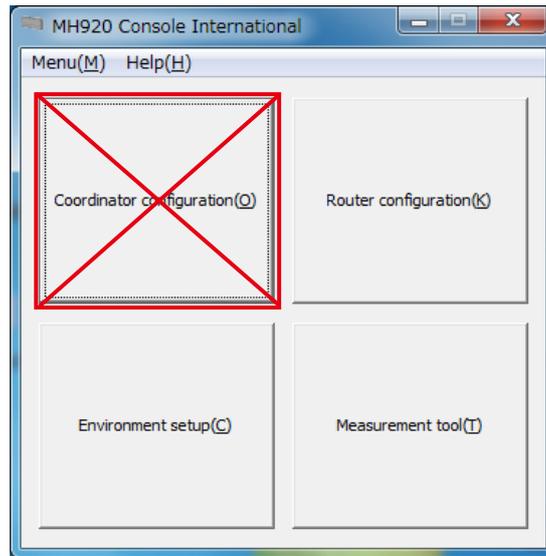
Figure 5.26 Maintenance Console Main screen

5.4.2 ROUTER CONFIGURATION

Not used.
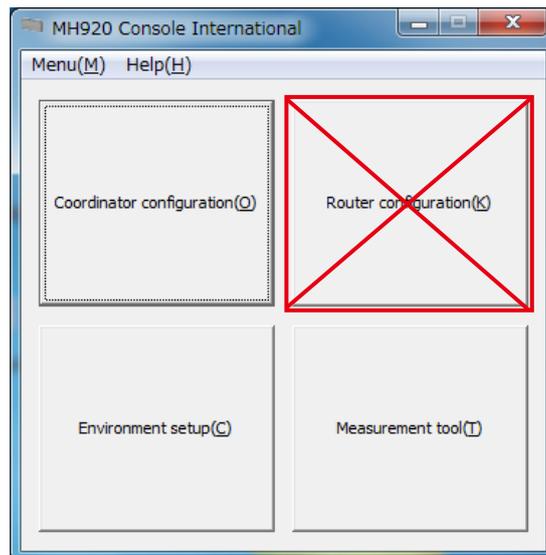
Figure 5.27 Maintenance Console Main screen

5.4.3 UPDATING FIRMWARE OF WIRELESS COMMUNICATION MODULE

Do not update the firmware of a wireless communication module incorporated in a wireless device, or we will not warrant the device.

6. PRELIMINARY MEASUREMENT OF RADIO WAVE ENVIRONMENT

In prior to building a wireless network, perform the following measurements to decide which channels to use and locations for installing respective wireless devices.
• Channel noise scan
• Communication test

Execute a channel noise scan to measure RSSI values of respective channels.

Check the channel numbers not used on the perimeter.

Execute a communication test to measure the RSSI value and packet error rate (PER) between wireless devices in a specific channel.

Determine the number of wireless devices, installation locations, and necessity to set relay nodes, etc. based on the RSSI value and the PER of each channel to use.

Note 1: To measure the radio wave environment, switch the mode of each wireless device from the normal mode to the measurement mode. To switch the mode, refer to "6.3 TERMINATING MEASUREMENT TOOL" on page 51.

Note 2: The wireless connection is disconnected when the PAN ID of a parent device is set to '0000'. Switch to the normal mode and change the PAN ID to, for example, '0001'. Refer to the operating manual of the parent device specified in "8. SETTING WIRELESS DEVICES" on page 62 for how to change the PAN ID.

Note 3: The wireless connection of a child device is disconnected when:
    no channel number is set;
    the short address is set to '0000'; and/or
    no network name is set.
Switch to the normal mode and change each setting item. Refer to the users manual of each child device specified in "8. SETTING WIRELESS DEVICES" on page 62 for how to change the setting of each item.

Note 4: Switch the mode to the normal mode to change the setting of 'Transmitter power output'. Refer to the manual of each wireless device specified in "8. SETTING WIRELESS DEVICES" on page 62 for how to change the setting.

6.1 CHANNEL NOISE SCAN

The maintenance console is equipped with the noise scan tool for measuring RSSI values of all the channels available or specific channels at regular time intervals.

6.1.1 STARTING CHANNEL NOISE SCAN

1) Connect a wireless device to the PC with the maintenance console via a mini USB cable, and turn on the power of the device.
2) Start the maintenance console and click [Environment setup] on the main screen to open the "Environment setup" screen.
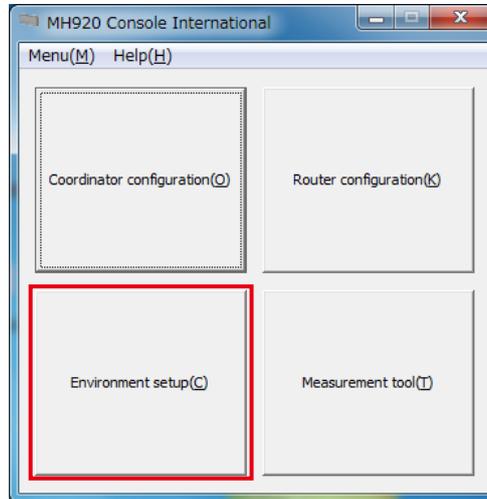
Figure 6.1 Maintenance console main screen

3) Click the pull-down button in the "COM port" column, select the COM port to which the wireless device is connected, and click [Set].
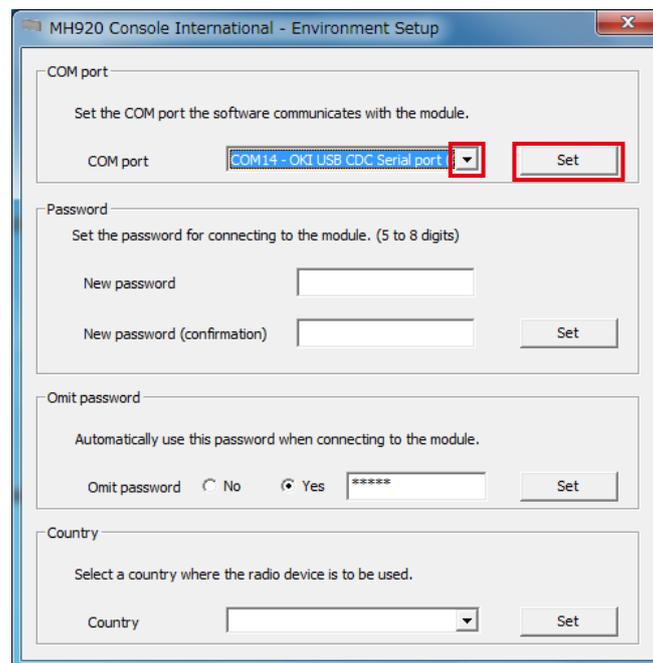
Figure 6.2 Environment setup

4) Close the "Environment setup" screen, and click [Measurement tool] on the main screen.
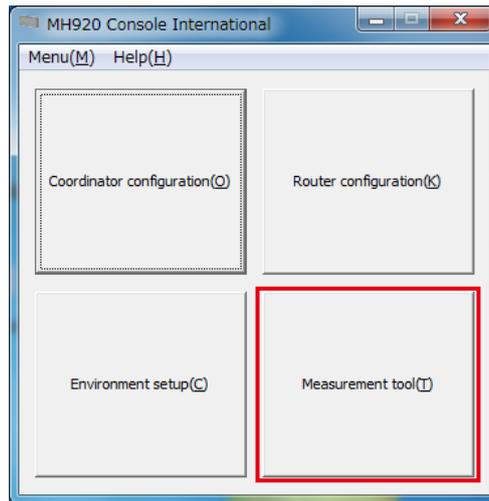
Figure 6.3 Maintenance console main screen

5) When the following screen appears, check 'Channel noise scan mode' and click [Change mode].
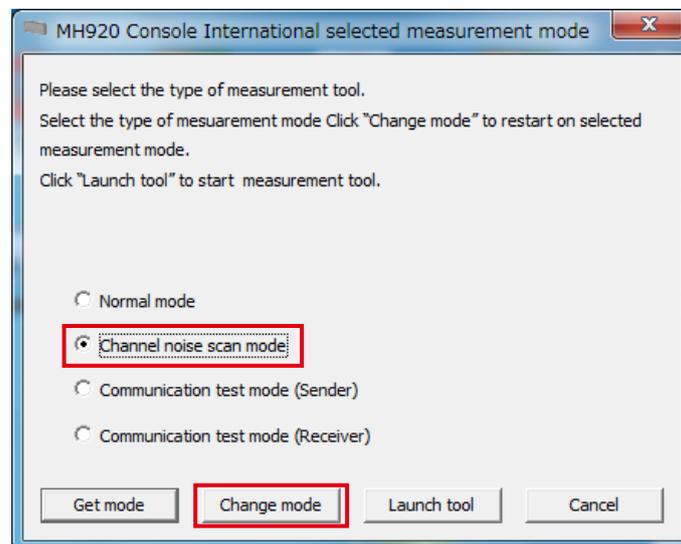
Figure 6.4 Selecting channel noise scan

6) When "Omit password" is set to 'No' on "Environment setup" screen, the password is required to connect with the wireless device. Enter the password and click [Connect].
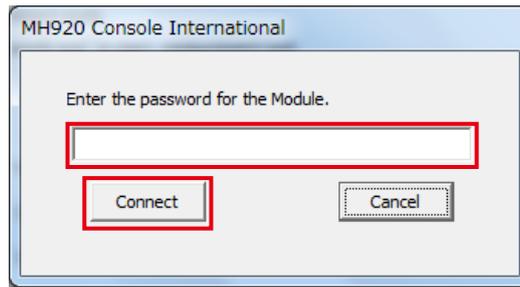
Figure 6.5 Password entry

7) When the following message appears, click [OK].
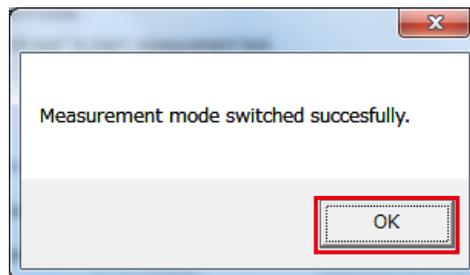
Figure 6.6 Confirming channel noise scan startup

8) Turn off the power of the device and reboot it.
9) Check 'Channel noise scan mode' and click [Launch tool].
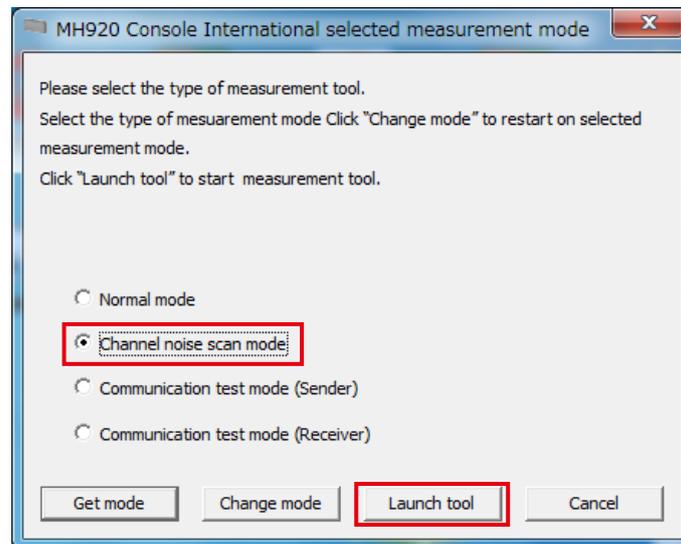
Figure 6.7 Starting channel noise scan

10) "Channel Noise Scan" screen appears.
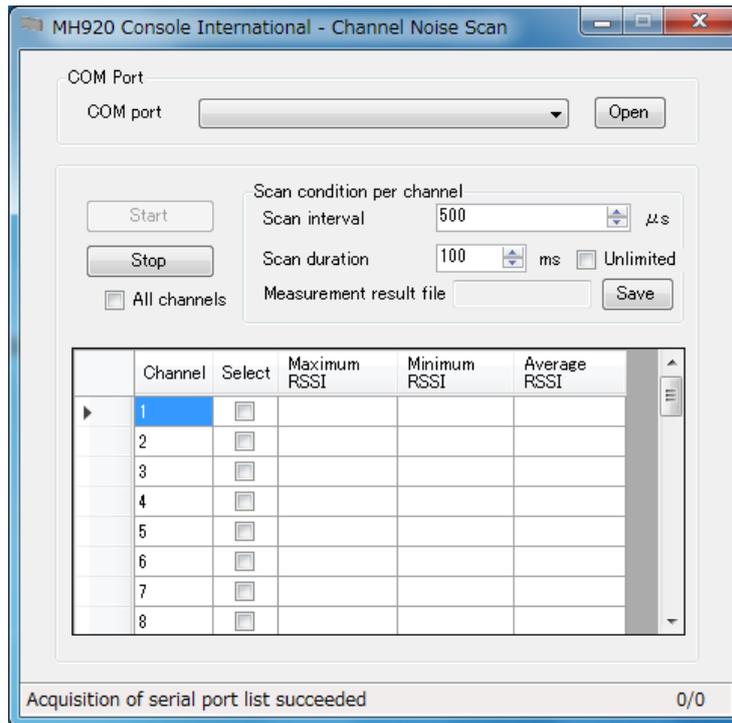
Figure 6.8 Channel noise scan

6.1.2 EXECUTING CHANNEL NOISE SCAN

Perform the channel noise scan according to the following procedure.

Do not turn off the power of the wireless device or remove the mini USB cable during the measurement, or an error message will appear and the channel noise scan tool will be forcibly terminated.

1) Click the pull-down button in the "COM port" column, select the COM port to which the wireless device is connected, and click [Open].
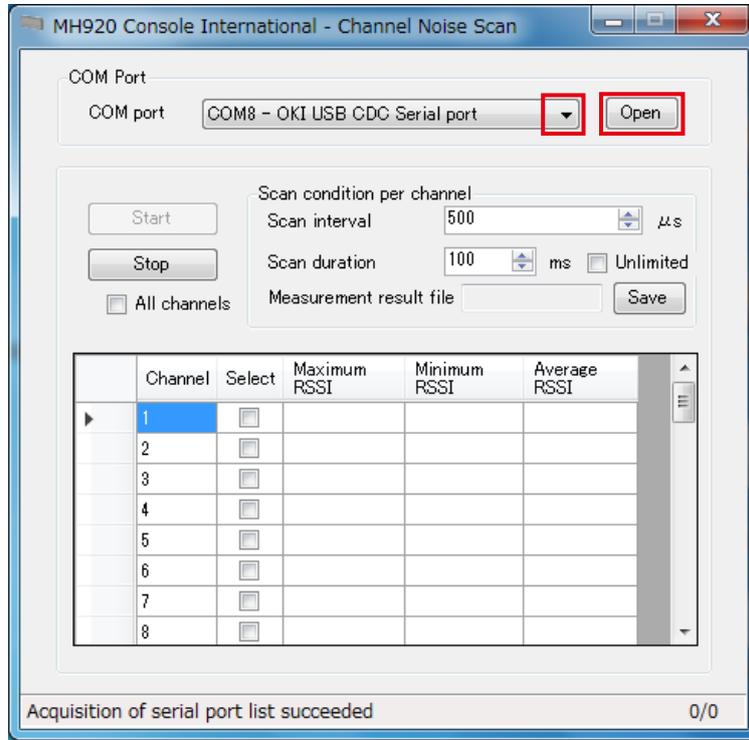
Figure 6.9 Selecting COM port

2) Specify 'Scan interval' and 'Scan duration'.
   When 'Unlimited' is checked, the measurement will infinitely continue.
   For example, set "Scan interval" to 500 μs and "Scan duration" to 100 msec., and 200 measurements will be carried out for 100 msec. at 500 μs interval per channel.
   [Number of times of channel noise scan per channel] = (scan duration [msec.] × 1000) ÷ scan interval [μs]
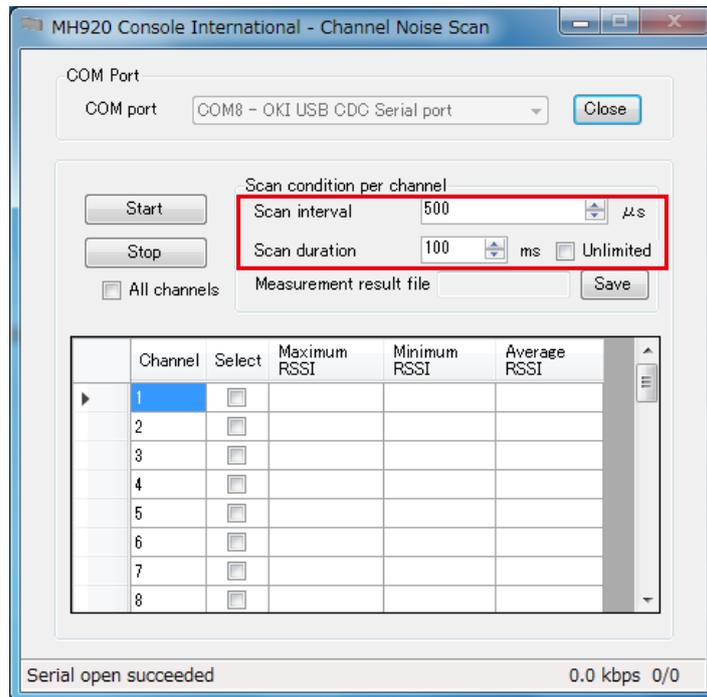
Figure 6.10 Specifying scan interval and duration

When 'Unlimited' is checked, the measurement continues until [Stop] button is clicked.
When 'Unlimited' is not checked, max. 2000 measurements are carried out.

3) Specify channels for which to perform measurement.
   Check applicable boxes in the "Select" column or check 'All channels'.
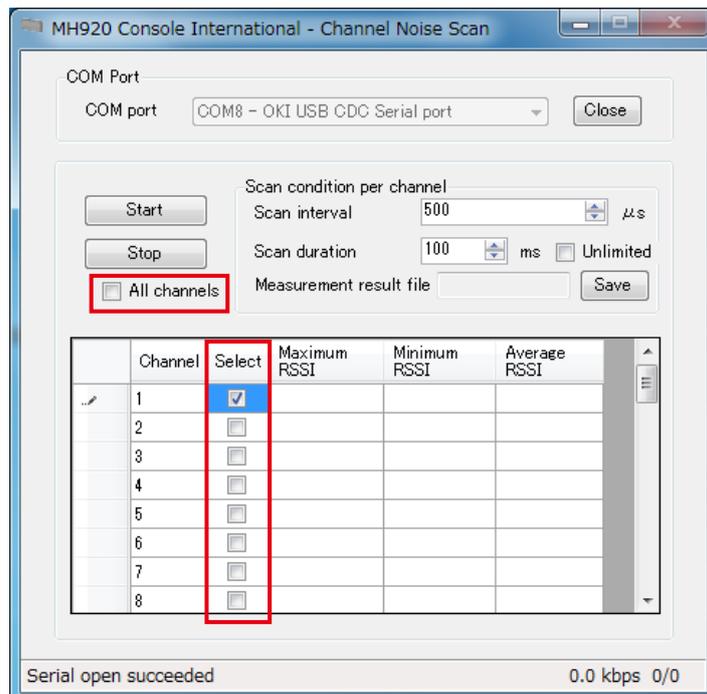
Figure 6.11 Specifying channels

4) Click [Save] button in the "Measurement result file" column to save measurement results in a specified folder with a specified file name.
The default save location and file name are as follows unless they are specified.
• Folder: ¥chnscan¥CH-Noise_Log¥
• File name: CHN_yymmdd-HHMMSS.csv
            yy: year, mm: month, dd: date, HH: hour, MM: minute, SS: second

[Table 6.1] Measurement result file contents

ITEM	EXPLANATIONS
Time of Day	Measurement time and date
Channel	Measured channels
Interval	Measurement interval [µs]
Times	Number of times of channel noise scans per channel
RSSI	Measured RSSI values
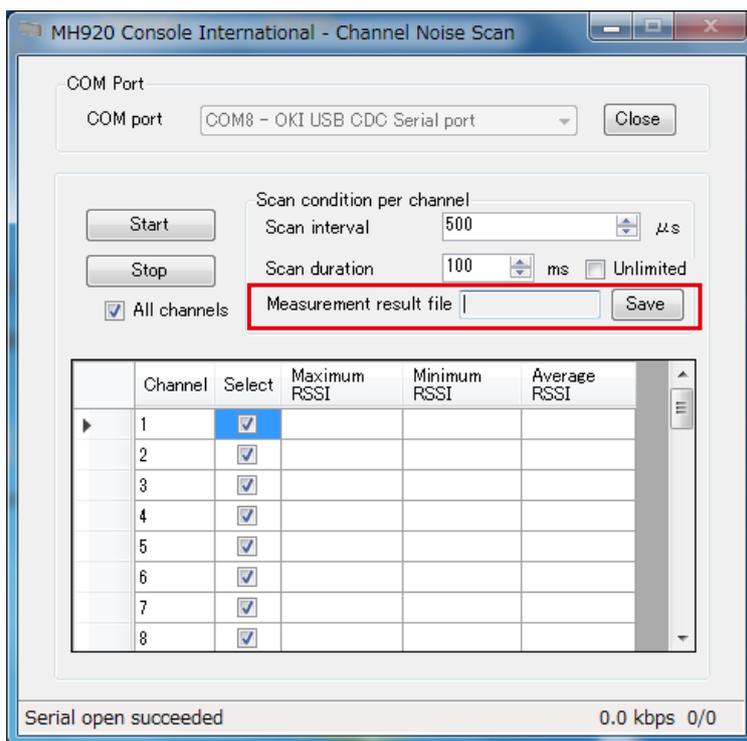
Figure 6.12 Specifying measurement result file

5) Click [Start] to start the measurement.
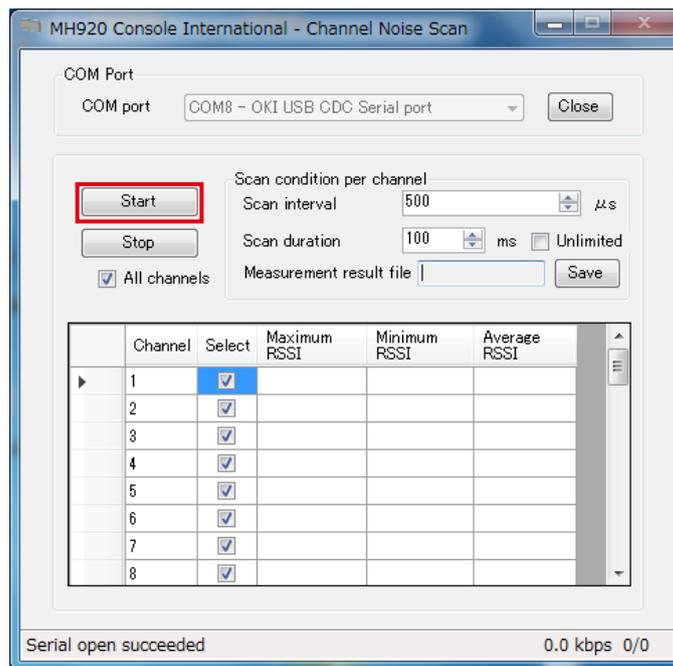
Figure 6.13 Starting measurement

6) The measurement results are displayed as shown in the screen below.
   When determining which channels to use based on the results, choose ones whose RSSI values are lower than others and whose adjacent channels have low RSSI values.
   Refer to "7.1.3 RADIO CHANNEL NUMBER" on page 54 for details.
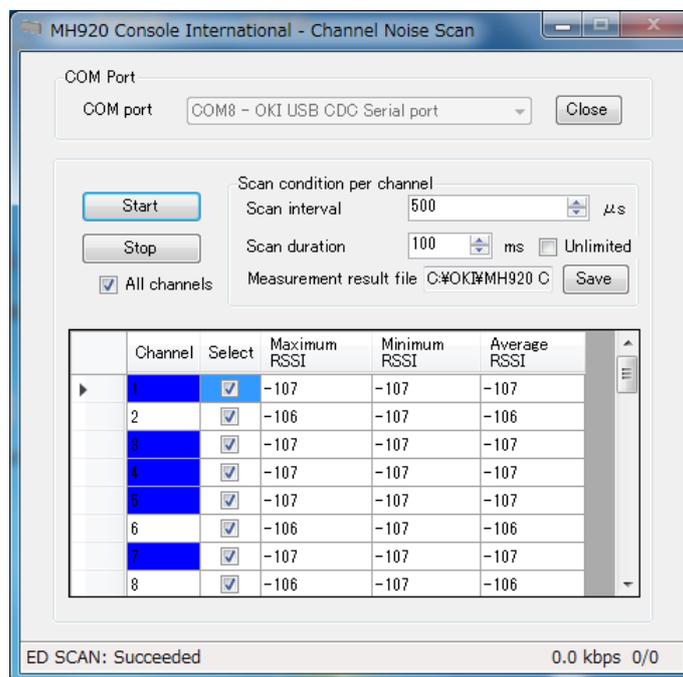
Figure 6.14 Measurement result

[Table 6.2] Measurement result contents

ITEM	EXPLANATIONS
Maximum RSSI	Max. RSSI value of the channel in the scan results
Minimum RSSI	Min. RSSI value of the channel in the scan results
Average RSSI	Average RSSI value of the channel in the scan results

Note: An average value can be greater than the maximum value or smaller than the minimum value because it is obtained by the logarithmic function and fraction calculation.

6.2 COMMUNICATION TEST

Perform the communication test between two wireless devices.

Use a pair of a parent device and a child or two child devices, and set one device as a sender and the other as a receiver.

Either device can be set to a sender or receiver.

Set one device as a sender first and then the other one as a receiver.

Take the following two steps to perform the communication test.

RSSI and PER (packet error rate) can be measured.

1. Setting sender
   Set a channel to measure.

2. Setting receiver
   Set the same channel as the sender.
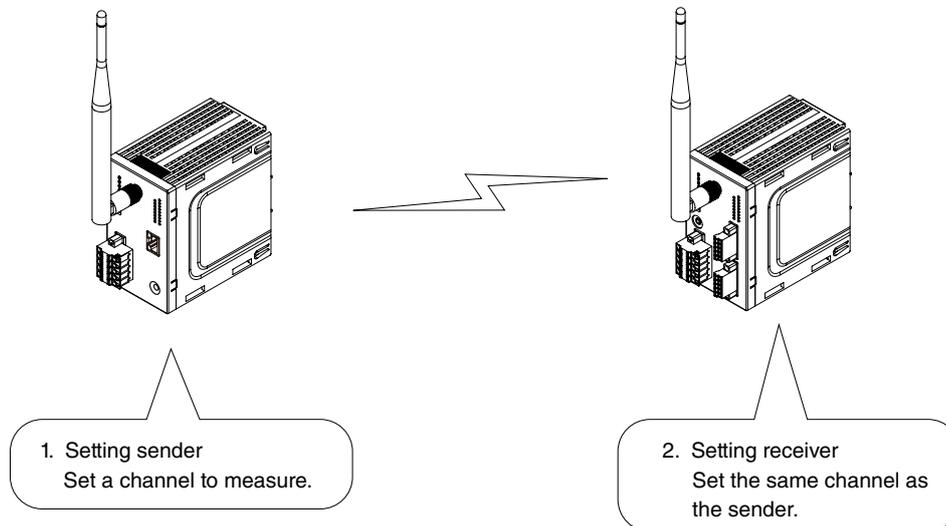
Figure 6.15 Configuration of communication test

6.2.1 SETTING SENDER

Set the first wireless device as a sender.
1) Both sleeve and rooftop antennas can be used.
2) The transmitter power output in the communication test is the value set in the device.
   Refer to the manual of the device to change the setting value, if necessary.
3) Connect the device to the PC with the maintenance console using a mini USB cable and turn on the power of the device.
4) Start the maintenance console and click [Environment setup] on the main screen to open "Environment setup" screen.
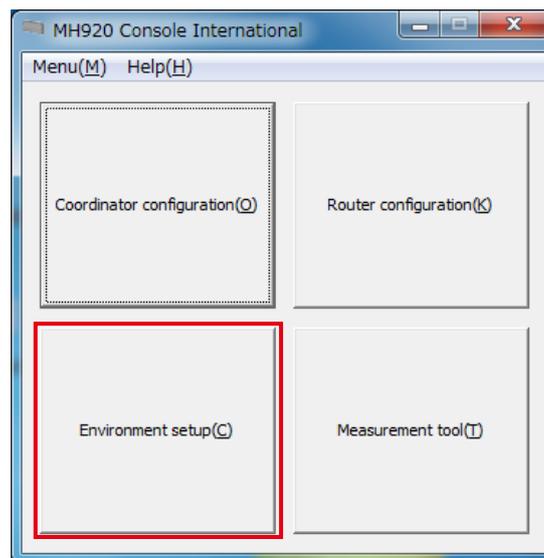
Figure 6.16 Maintenance console main screen

5) Click the pull-down button in the "COM port" column, select the COM port to which the device is connected, and click [Set].
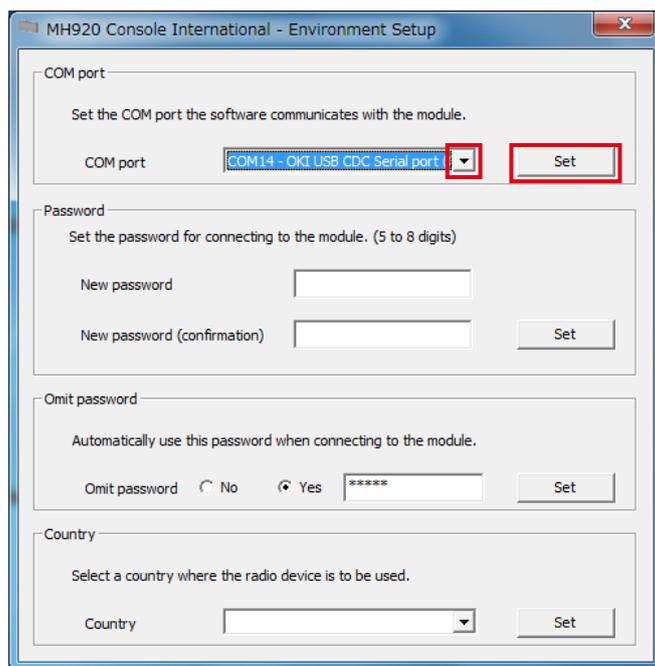
Figure 6.17 Environment setup

6) Close "Environment setup" screen, and click [Measurement tool] button on the main screen.
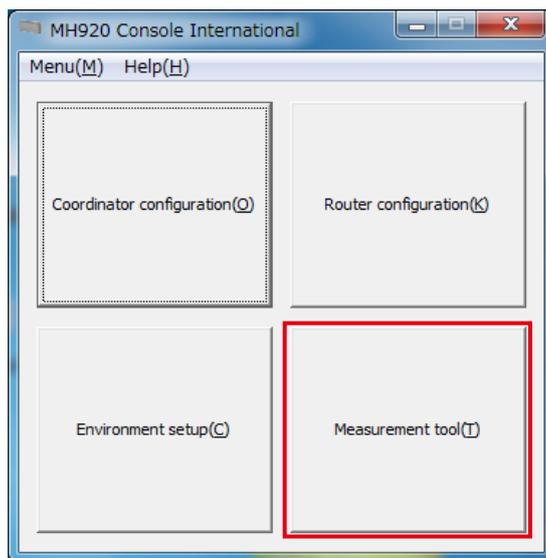
Figure 6.18 Maintenance console main screen

7) When the following screen appears, check 'Communication test mode (Sender)' and click [Change mode].
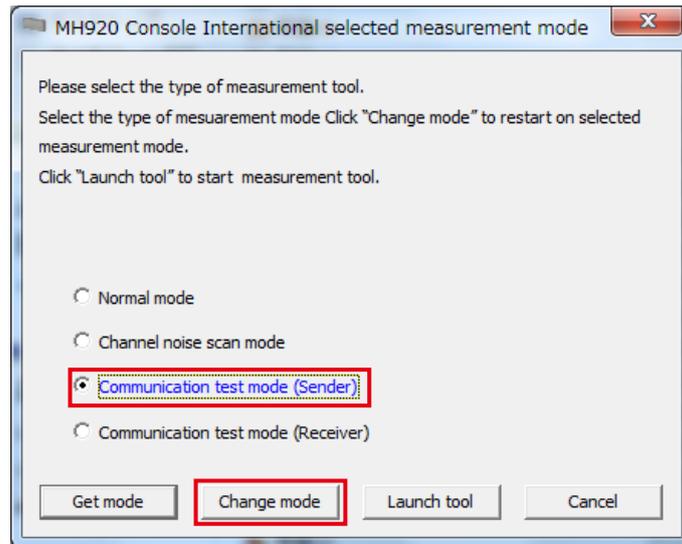
Figure 6.19 Selecting communication test (Sender)

8) When "Omit password" is set to 'No' on "Environment setup" screen, the password is required to connect to the wireless device. Enter the password and click [Connect].
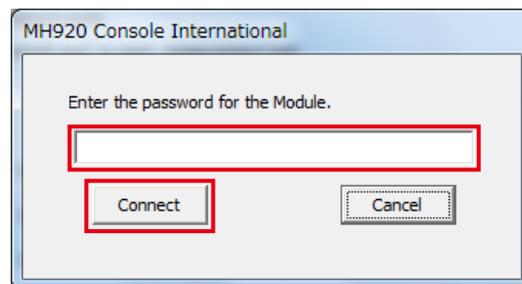
Figure 6.20 Password entry

9) When the following message appears, click [OK].
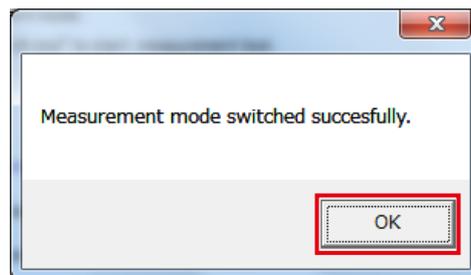
Figure 6.21 Confirming communication test (Sender) startup

10) Turn off the power of the device and reboot it.
11) Check 'Communication test mode (Sender)' and click [Launch tool].
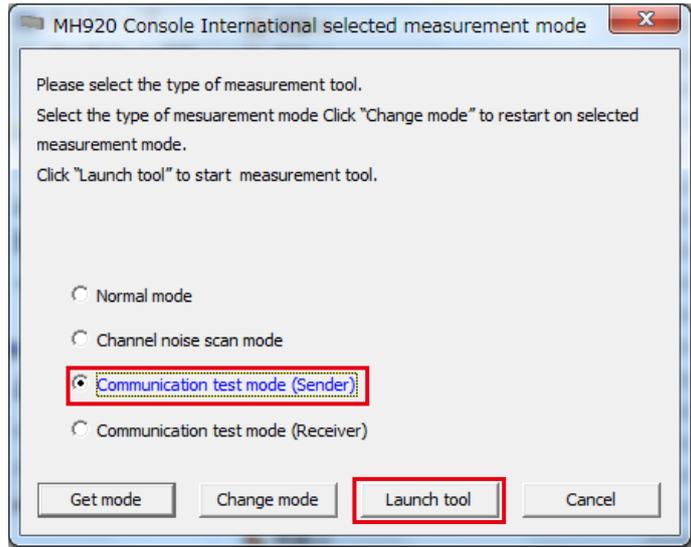
Figure 6.22 Starting communication test (Sender)

12) When the following screen appears, click the pull-down button in the "COM port" column, select the COM port to which the wireless device to be set as a sender is connected, and click [Open].
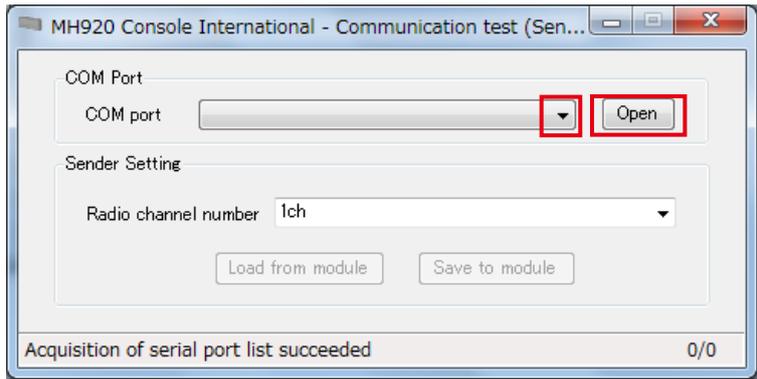
Figure 6.23 Selecting COM port

13) Specify the radio channel number.
    To use the channel already set in the device, click [Load from module].
    To specify a new channel number, click the pull-down button in the "Radio channel number" column, select a channel, and click [Save to module].
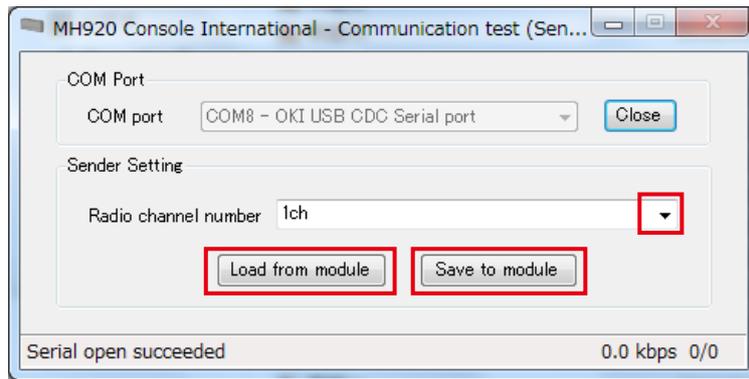
Figure 6.24 Setting sender (channel number)

14) A message "Serial open succeeded" is displayed at the lower left of the console screen.
    The sender setting is now complete.
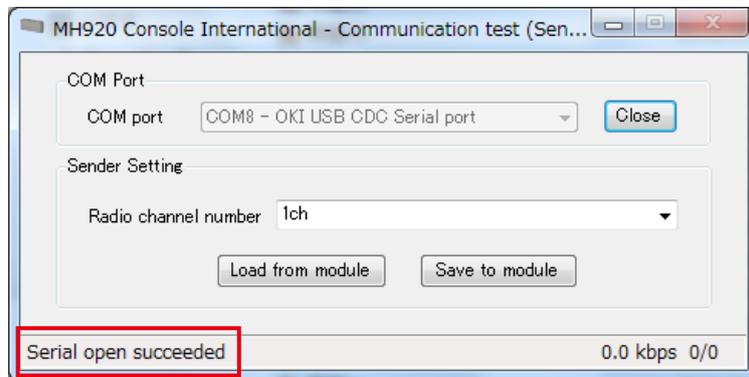
Figure 6.25 Sender setting complete

6.2.2 SETTING RECEIVER

Set the second wireless device as a receiver.

Do not perform other operations than measurement of RSSI and PER after the receiver setting is complete.

To perform other operations, terminate the measurement tool (refer to "6.3 TERMINATING MEASUREMENT TOOL" on page 51) and return to the normal mode.

1) Both sleeve and rooftop antennas can be used.
2) Connect the device to the PC with the maintenance console using a mini USB cable and turn on the power of the device.
3) Start the maintenance console and click [Measurement tool] on the main screen.
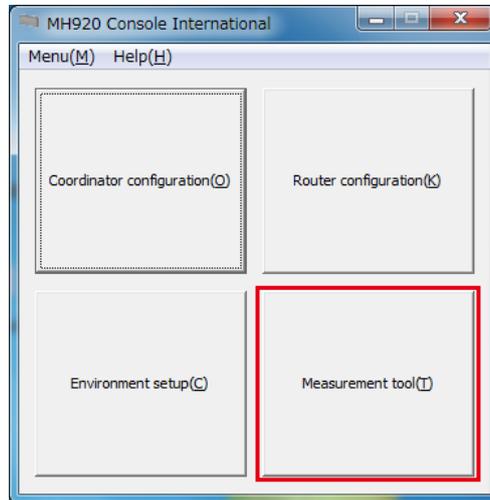
Figure 6.26 Maintenance console main screen

4) When the following screen appears, check 'Communication test mode (Receiver)' and click [Change mode].
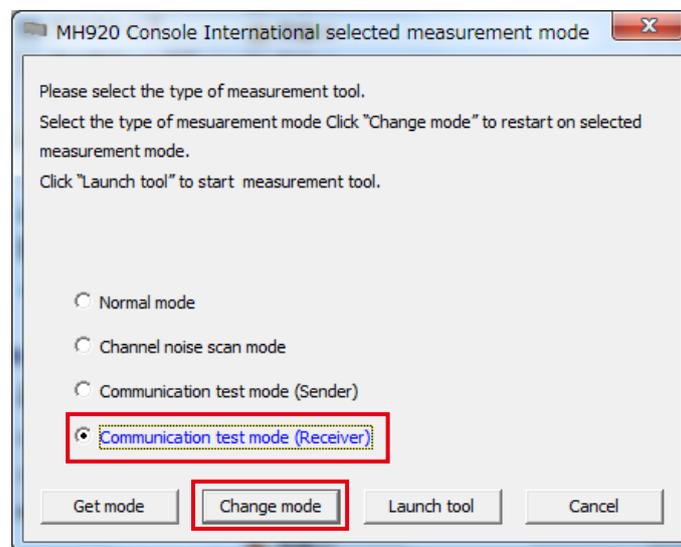
Figure 6.27 Selecting communication test (Receiver)

5) When "Omit password" is set to 'No' on "Environment setup" screen, the password is required to connect to the wireless device. Enter the password and click [Connect].
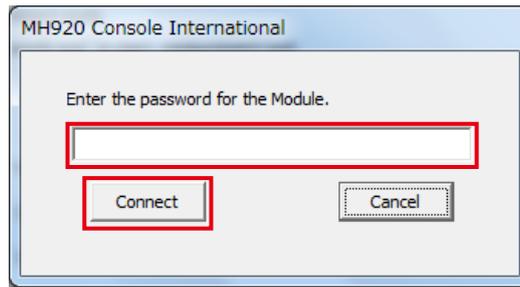
Figure 6.28 Password entry

6) When the following message appears, click [OK].
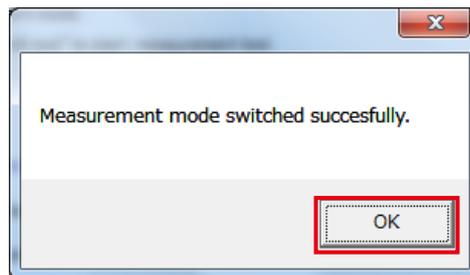
Figure 6.29 Confirming communication test (receiver) startup

7) Turn off the power of the device and reboot it.
8) Check 'Communication test mode (Receiver)' and click [Launch tool].
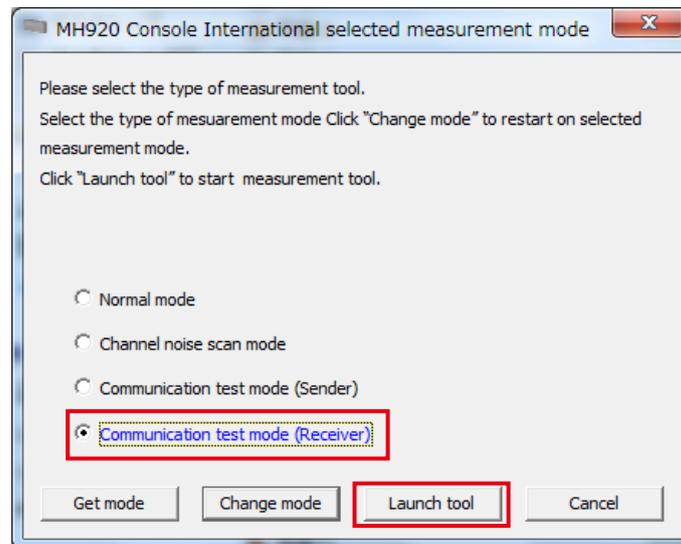
Figure 6.30 Starting communication test (Receiver)

9) When the following screen appears, click the pull-down button in the "COM port" column, select the COM port to which the wireless device to be set as a receiver is connected, and click [Open].
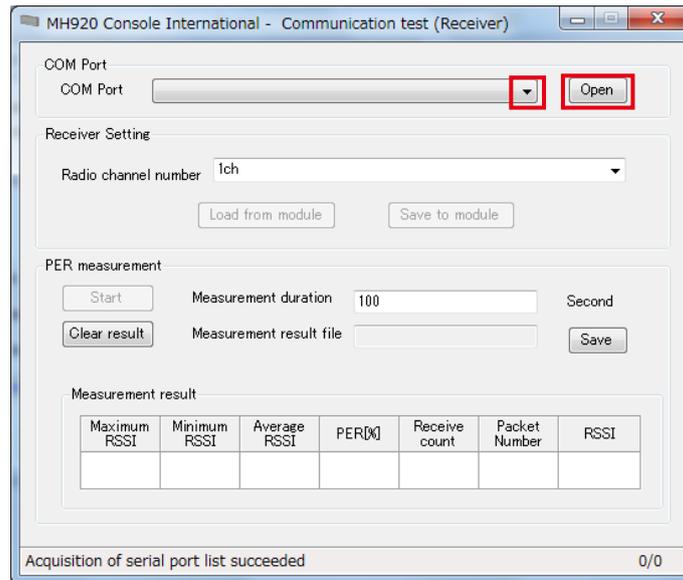
Figure 6.31 Selecting COM port

10) Specify a radio channel number.
   To use the channel already set in the device, click [Load from module].
11) To specify a new channel, click the pull-down button in the "Radio channel number" column, select a channel number and click [Save to module].
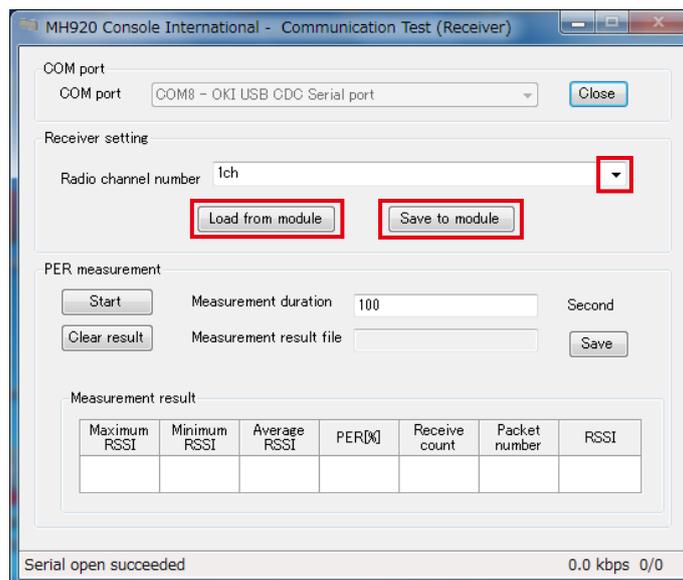
Figure 6.32 Setting receiver (channel number)

The receiver setting is now complete.

6.2.3 MEASURING RSSI AND PER

Execute the measurement with the wireless device set as a receiver.

1) Specify "Measurement duration" within the range of 1 to 600000 seconds on "Communication test (Receiver)" screen.
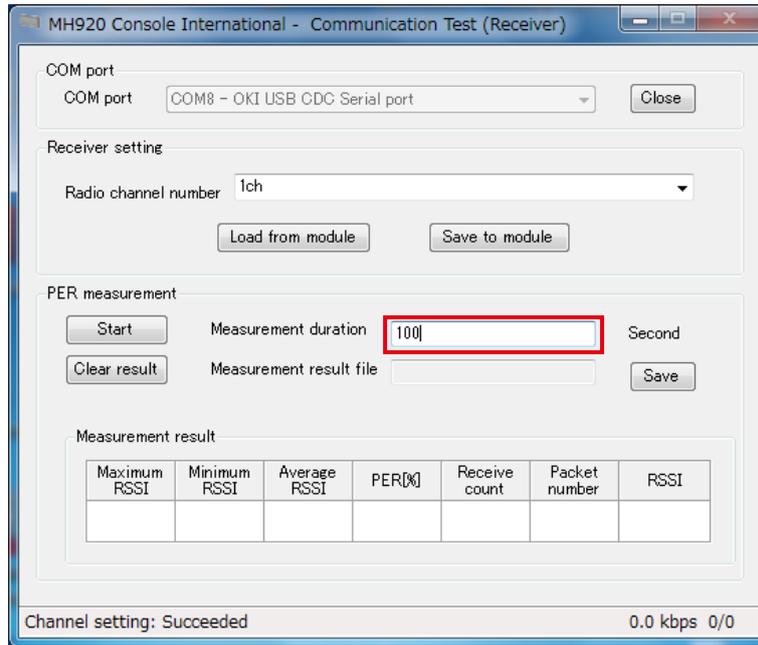
Figure 6.33 Specifying measurement duration

Click [Save] button in the "Measurement result file" column to save measurement results in a specified folder with a specified file name.

The default save location and file name are as follows unless they are specified.
• Folder: ¥PER_Log under the installation folder
• File name: PER_yymmdd-HHMMSS.csv
   yy: year, mm: month, dd: date, HH: hour, MM: minute, SS: second

[Table 6.3] Measurement result file contents

ITEM	EXPLANATIONS
Maximum RSSI [dBm]	Max. RSSI value in the measurement result
Minimum RSSI [dBm]	Min. RSSI value in the measurement result
Average RSSI [dBm]	Average RSSI value in the measurement result
PER [%]	Packet error rate in the measurement duration
Receive count	Number of packets received in the measurement duration
Packet Number	Latest received packet number (number of the packet the sender transmitted)
RSSI	RSSI value in receiving the latest packet
Ch Number	Measured radio channel
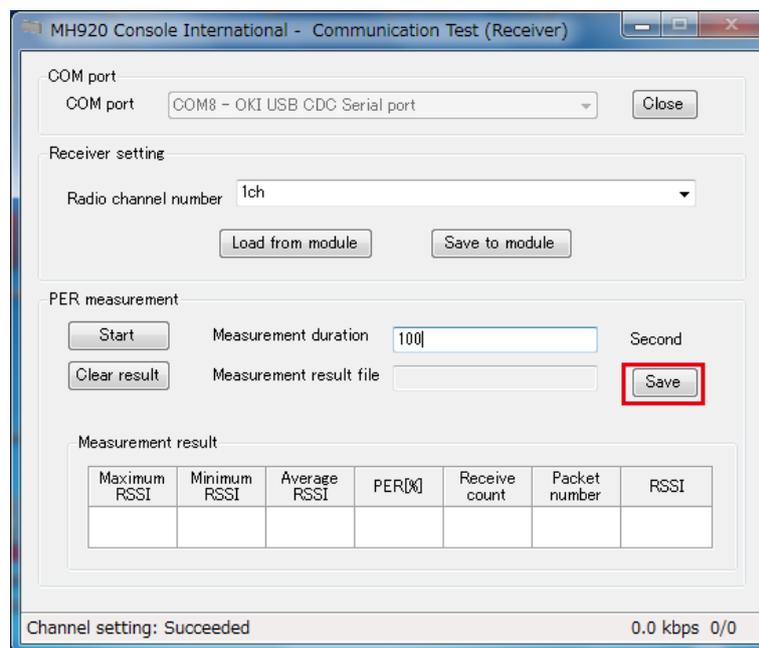
Figure 6.34 Specifying measurement result file

2) Click [Start] to start the measurement.
   When the measurement is complete, values are displayed in the respective columns of "Measurement result," and the measurement result file is saved.
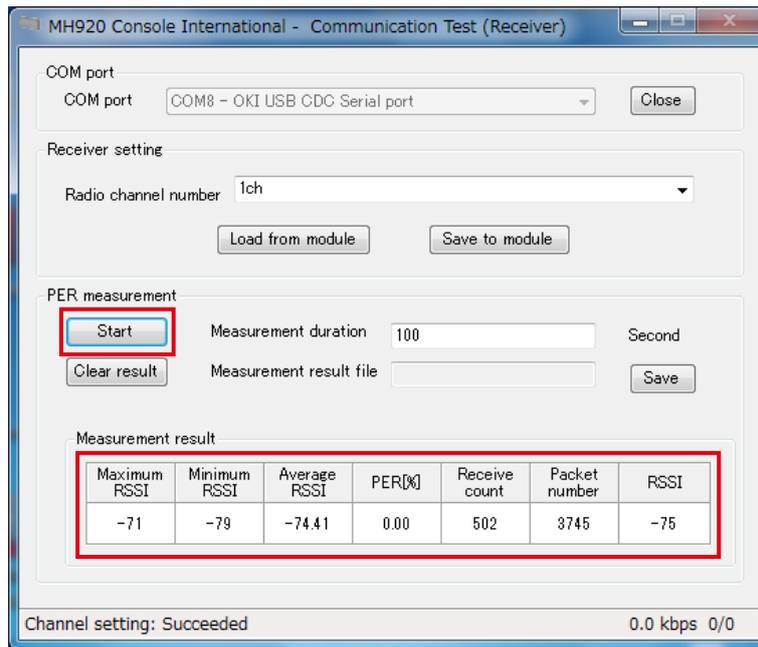
Figure 6.35 Measurement result

[Table 6.4] Measurement result

ITEM	EXPLANATIONS
Maximum RSSI [dBm]	Max. RSSI value in the measurement result
Minimum RSSI [dBm]	Min. RSSI value in the measurement result
Average RSSI [dBm]	Average RSSI value in the measurement result
PER [%]	Packet error rate in the measurement duration
Receive count	Number of packets received in the measurement duration
Packet Number	Latest received packet number (number of the packet the sender transmitted)
RSSI	RSSI value in receiving the latest packet

When the child device is installed in a fixed manner, it is recommended to operate it with the PER less than 0.01 % and the average RSSI -85 dBm or more.

When the child device is used on a low-speed moving device, it is recommended to operate it with the PER less than 0.01 % and the average RSSI -75 dBm or more.

These values are not essential.

To determine the feasibility of installation, set your own reference PER considering the error rate allowed by the system or environment in which the device is used.

6.3 TERMINATING MEASUREMENT TOOL

Terminate the measurement tool (channel noise scan or communication test) according to the following procedure.

1) Click [Close] button in the "COM port" column on the channel noise scan or communication test (Sender or Receiver) screen and confirm that [x] button in the upper right corner is activated.
   Click [x], then click [OK].
   Terminate the communication test for both sender and receiver.
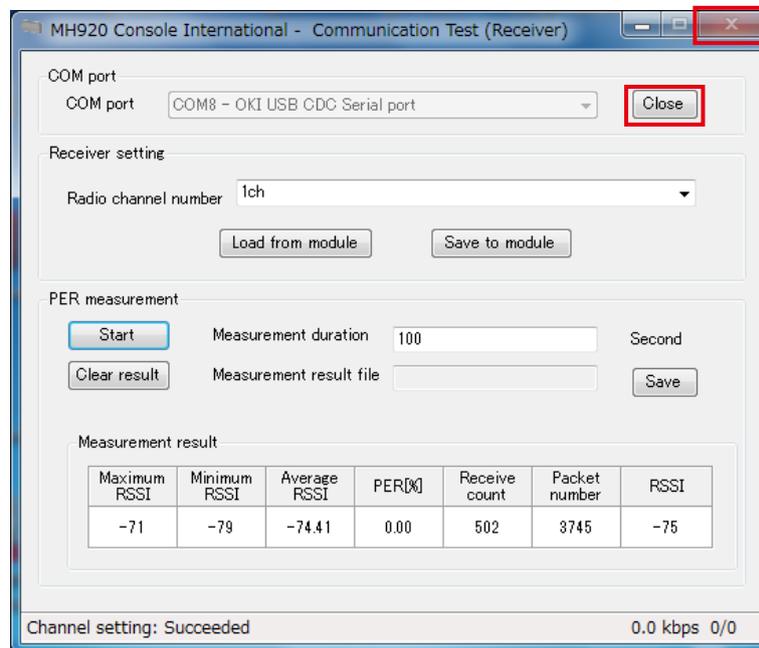
Figure 6.36 Terminating measurement tool

2) When the mode selection screen appears, check 'Normal mode'.
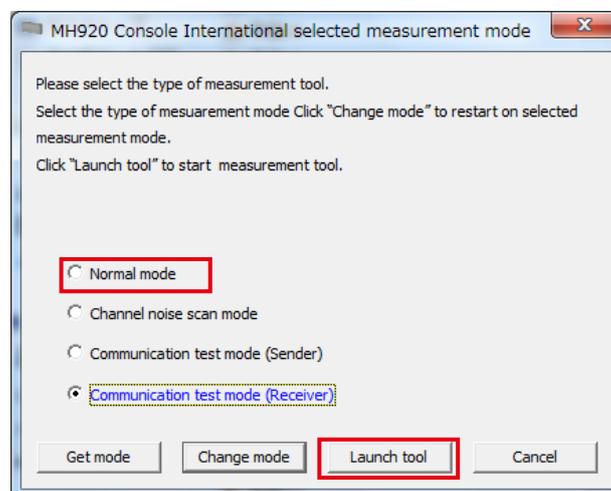
Figure 6.37 'Communication test mode (Receiver)' selected

3) Click [Change mode].
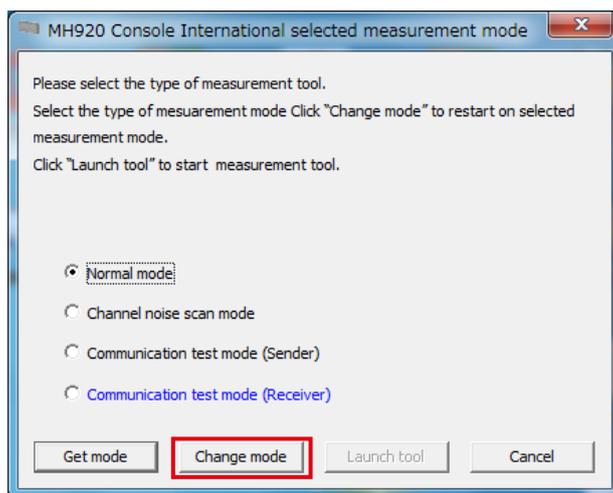
Figure 6.38 'Normal mode' selected

4) When the following message appears, click [Yes].
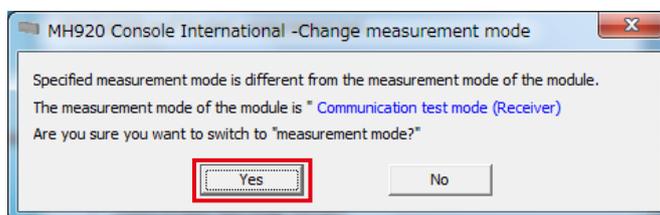
Figure 6.39 Switching measurement mode

5) The wireless device reboots in the normal mode and the following message appears.
Click [OK].
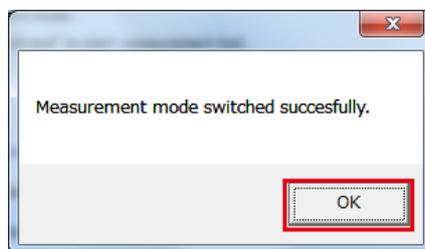
Figure 6.40 Successful mode switching message

7. EXAMINING PARAMETERS OF WIRELESS DEVICES

To configure a multihop network using wireless devices, decide each parameter as shown below.

[Table 7.1] Parameters

PARAMETER	PARENT	CHILD	REMARKS
Network join mode	✓	✓	Identically set in both parent and child devices.
PAN ID (group number)	✓	✓	Identically set in both parent and child devices.
Radio channel number	✓	✓	Identically set in both parent and child devices.
Network name	✓	✓	Identically set in both parent and child devices.
Transmitter power output	Δ	Δ	
Retry times before route switching	Δ	Δ	
Encryption key	✓	✓	Identically set in both parent and child devices.
MAC address authentication	Δ	✕	Set in a parent device.
MAC address list	Δ	✕	Set in a parent device.
Connection refusal list	Δ	✕	Set in a parent device.
Low-speed moving mode	✕	✓	Set in child devices.
Prefix	Δ	✕	Set in a parent device.
Short address	✕	✓	Fixed to 0000 in a parent device. Individually set addresses in respective child devices.
Packet filtering	✓	✓	Identically set in both parent and child devices.
Setting mode of short address	✓	✕	Set in a parent device.
Station number list	*1	✕	*1. Available when set to 'list mode' for "Setting mode of short address"
Fixed route	✕	Δ	
Device type in a network, Number of devices in a network	✓	✓	Identically set in both parent and child devices.
Set network quality	Δ	Δ	Identically set in both parent and child devices.
Password for device connection	*2	*2	*2. The value can be left at default, however, it is recommended to change it to a new one.

✓: Setting required

✕: Setting Not available

Δ: The value can be left at default

7.1   PARAMETERS

7.1.1   NETWORK JOIN MODE

The network join mode is selectable between 'fast join mode' and 'v3-compatible mode' for wireless devices in the network.

'Fast join mode' allows a faster connection to the network, in approximately 5 seconds at the fastest.

Select 'v3-compatible mode' when the network includes wireless devices moving at low speed.

It takes for a wireless device to join the network approximately 30 seconds at the fastest.

Note that all the wireless devices in the network must be set to the same mode.

[Table 7.2] Network join mode

DEVICE	SETTING	SPECIFICATIONS / RANGE	REMARKS
Parent	Required	Fast join mode / v3-compatible mode	
Child	Required	Fast join mode / v3-compatible mode	

7.1.2   PAN ID (GROUP NUMBER)

Wireless devices configure a wireless multihop network (wireless PAN: Personal Area Network) under a parent device.

The parent device configures a PAN using the preset channel number (frequency band) and imparts the preset own PAN ID as identifier to the PAN.

Set the PAN ID so as not to overlap with that of other networks (parent device), and set this ID to child devices to be connected thereto.

Set a PAN ID within the range as shown in "Table 7.3 PAN ID".

[Table 7.3] PAN ID

DEVICE	SETTING	SPECIFICATIONS / RANGE	REMARKS
Parent	Required	Hexadecimal, 4 digits 0x0001 − 0xFFFE	Set to a value that does not overlap with that of other parent devices.
Child	Required	Hexadecimal, 4 digits 0x0001 − 0xFFFE	Set the same value as the parent device to which to connect.

Note: The wireless connection is disconnected when set to '0x0000'.

7.1.3   RADIO CHANNEL NUMBER

Select one channel from among 8 channels in the table below and set the channel to a parent device to configure a wireless network (PAN).

Set a different channel number from the ones of other wireless devices in the range where the radio wave reaches, or overlapping channels may cause radio wave interference and prevent normal communication.

[Table 7.4] Radio channel number

Radio channel number	Center frequency
1	920.4 MHz
2	921.0 MHz
3	921.6 MHz
4	922.2 MHz
5	922.8 MHz
6	923.4 MHz
7	924.0 MHz
8	924.6 MHz

Set a radio channel number not used on the perimeter to a parent device.

To each child device, set the radio channel number of the parent device to which to connect.

Up to 8 channel numbers can be specified to a child device.

With multiple channel numbers, it takes time for channel scanning in the network search, resulting longer time to join the network.

7.1.4 NETWORK NAME

An identifier, called network name, can be given to a network so that child devices can connect to the correct parent device even when several parent devices are installed adjacently.

Up to 16 English one-byte characters and some symbols (one-byte space, "-", "_", "." and "@") are usable.

Register a network name to all the parent and child devices.

A child device cannot connect to a parent device with a network name different from that set to the child device.

Using this network name, a PAN which is individually configured by each parent device can function as one network.

Set a network name as shown in the table below.

[Table 7.5] Network name

DEVICE	SETTING	SPECIFICATIONS / RANGE	REMARKS
Parent	Essential	English one-byte characters and symbols within 16 characters*	Set to a value that does not overlap with that of other parent devices.
Child	Essential	English one-byte characters and symbols within 16 characters*	Set the same value as the parent device to which to connect.

* One-byte space, "-", "_", "." and "@"are usable.

7.1.5 TRANSMITTER POWER OUTPUT

The radio wave reachable distance changes depending on the transmitter power output.

The transmitter power output is selected from 20 mW, 1 mW, and 0.16 mW.

[Table 7.6] Transmitter power output

DEVICE	SETTING	SPECIFICATIONS / RANGE	REMARKS
Parent	Required	20mW / 1mW / 0.16mW	
Child	Required	20mW / 1mW / 0.16mW	

7.1.6 RETRY TIMES BEFORE ROUTE SWITCHING

Select the number of times to retry transmission before switching the route when the communication through a route from a parent device to repeaters or child devices (hereafter referred to as 'downstream route') fails.

Select the number of times from 1, 2, and 3 times.

When the retry times is set to 1, the switching time can be shortened and a route in better communication state is selected when a communication error occurs.

However, there is a risk that a communication error due to just temporary fluctuation of radio wave can cause the route switching and a communication route in good communication state may be switched.

Based on the above, 3 retry times is balanced well between switching frequency and communication reliability.

[Table 7.7] Retry times before route switching

DEVICE	SETTING	SPECIFICATIONS / RANGE	REMARKS
Parent	Required	1 / 2 / 3	
Child	Required	1 / 2 / 3	

7.1.7 SECURITY DESIGN

Each child device needs to be authenticated by a parent device to join a wireless multihop network.

There are two authentication methods as follows.
- Encryption key authentication
- MAC address authentication

Refusal of specific child devices to join the network is possible by the following method.
- Connection refusal with MAC address

All wireless devices need encryption key authentication registration/setting to join the network.

MAC address authentication is arbitrary.

Using these two methods in combination realizes more enhanced security.

■ ENCRYPTION KEY AUTHENTICATION

The wireless multihop network adopts wireless communication coded with the AES cryptographic algorithm, in the similar manner as other wireless networks such as Wi-Fi.

In joining the network, each child device needs to obtain a genuine encryption key necessary to encrypt and decrypt from a parent device. The encryption key must be registered to the child devices in advance.

Specify the encryption key in 32 hexadecimal digits.

This encryption key is also used in data communication on the network.

Thus, the key of the child devices needs to be the same as that of the parent device when the participation is authenticated only by the encryption key.

Set the encryption key in accordance with the table below.

[Table 7.8] Encryption key

DEVICE	SETTING	SPECIFICATIONS / RANGE	REMARKS
Parent	Required	Hexadecimal, 32 digits	
Child	Required	Hexadecimal, 32 digits	Set the same key as that of the parent device.

■ MAC ADDRESS AUTHENTICATION

It is necessary to register MAC addresses of child devices, which are to be authenticated to participate in the network, to a parent device in advance.

In this way, only the registered child devices can join the network.

With the MAC address authentication, it is possible to refuse the participation of a child device in the network from a malicious third party.

In case of MAC address authentication, different encryption keys can be set to individual child devices.

Up to 200 MAC addresses can be registered.

The MAC addresses can be confirmed with the configuration tool of the wireless devices.

[Table 7.9] MAC address authentication

DEVICE	SETTING	SPECIFICATIONS / RANGE	REMARKS
Parent	Required	No / Yes	

■ CONNECTION REFUSAL BASED ON MAC ADDRESS

In preparation for attacks from malicious third parties by MAC address spoofing or abuse of stolen devices, MAC addresses of such wireless devices can be registered in the 'connection refusal list' so that participation of wireless devices having those MAC addresses in the network can be refused.

7.1.8 LOW-SPEED MOVING MODE

Specify whether a child device is installed at a fixed position or in a device moving at low speed.

[Table 7.10] Low-speed moving mode

DEVICE	SETTING	SPECIFICATIONS / RANGE	REMARKS
Child	Required	No / Yes	No: fixed Yes: low-speed moving

7.1.9 IPV6 PREFIX

Child devices which are authenticated to join the multihop network obtain their IPv6 addresses and join the network.

Set a network prefix (leading 64 bits of IPv6 address) to a parent device to configure the addresses.

The IPv6 addresses for wireless devices are automatically set combining this prefix set to the parent device and short addresses set to individual parent and child devices.

The IPv6 addresses are configured according to the following flow.

1) Set a prefix to the parent device.
2) The parent device automatically sets its own IPv6 address using this prefix. (The short address of the parent device is fixed to 0.)
3) Set fixed short addresses to child devices.
4) The child devices obtain the information on the adjacent wireless devices and the prefix.
5) The child devices automatically set their IPv6 addresses using the prefix and their short addresses.
6) Each child device notifies the parent device of its own IPv6 address.
7) The parent device notifies the child device of the availability of the IPv6 address.
   Hereafter, the parent device manages the addresses of the wireless devices under its control.

Use the IPv6 global unicast address (leading 16 bits defined with 2000 to 3FFF as shown in the figure below) to set a prefix to the parent device. Do not replace consecutive groups containing zeros with single empty group using two consecutive colons (::), although it is common to represent an IPv6 address.
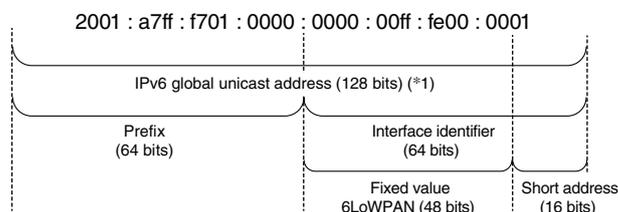
Figure 7.1 Configuration of IPv6 address

Set any prefix since the IPv6 communication is used only in the closed wireless segment.

However it is recommended to set a unique prefix to each parent device for the network management.

Set a prefix as shown in the table below.

[Table 7.11] Prefix

DEVICE	SETTING	SPECIFICATIONS / RANGE	REMARKS
Parent	Required	Leading 64 bits of IPv6 global unicast address	Do not use ":::" to omit zeros.

7.1.10 STATION NUMBER AND SHORT ADDRESS

To collect data from remote I/Os connected to wireless devices, it is necessary for a parent device to associate short addresses set to child devices with Modbus station numbers of the remote I/Os by either of following methods.
• List mode
• Range mode

Select a mode as shown in the table below.

[Table 7.12] Setting mode of short address

DEVICE	SETTING	SPECIFICATIONS / RANGE	REMARKS
Parent	Required	List mode Range mode: max. No. of multi-drops of 1 device Range mode: max. No. of multi-drops of 1 to 4 device Range mode: max. No. of multi-drops of 1 to 8 devices Range mode: max. No. of multi-drops of 1 to 16 devices Range mode: max. No. of multi-drops of 1 to 31 devices	

■ LIST MODE

The list mode is a method to register the combination of the Modbus station numbers and the short addresses of the child devices on the station number list of the parent device.
1) Modbus station number
   Set station numbers of the Modbus devices connected to the child devices.
2) Short address
   Set short addresses to the parent and child devices. The address of the parent device is fixed to 0000.
   Set short addresses to the child devices within the range of 0001 to FFFD in 4-digit hexadecimal.
   Set the short addresses so as not to overlap with each other.
3) Registration of the station numbers and the short addresses of the child devices
   Register the combination of the short addresses of the child devices and the station numbers of the Modbus devices on the station number list of the parent device.

■ RANGE MODE

The range mode is a method to assign the station numbers of the Modbus devices to the short addresses of the child devices within the specified range.
1) Max. No. of multi-drops
   Set to the child devices capable of multi drop connection.
   Decide the max. number, to be set to the parent device, of devices to be connected based on the number of devices actually connected in multi-drop in the network.
   Select among 1, 1 to 4, 1 to 8, 1 to 16, and 1 to 31 devices so as to be greater than the number of devices actually connected.
2) The number of devices to be connected
   The configurable station numbers depend on the max. No. of multi-drops set to the parent device.
   A part of the range of configurable station numbers is as shown in the table below.

[Table 7.13] Range of configurable station numbers

SHORT ADDRESS OF CHILD DEVICE	Max. No. of multi-drops				
	CONFIGURABLE STATION NUMBER				
	1	4	8	16	31
0001	1	1 – 4	1 – 8	1 – 16	1 – 31
0002	2	5 – 8	9 – 16	17 – 32	32 – 62
0003	3	9 – 12	17 – 24	33 – 48	63 – 93
0004	4	13 – 16	25 – 32	49 – 64	94 – 124
0005	5	17 – 20	33 – 40	65 – 80	125 – 155
0006	6	21 – 24	41 – 48	81 – 96	156 – 186
0007	7	25 – 28	49 – 56	97 – 112	187 – 217
0008	8	29 – 32	57 – 64	113 – 128	218 – 247 *1
0009	9	33 – 36	65 – 72	129 – 144	
000A	10	37 – 40	73 – 80	145 – 160	

*1. Modbus protocol allows up to 247 child devices to connect.

3) Short address and Station number

Set short addresses to the parent and child devices. The address of the parent device is fixed to 0 (0x0000).

Set the short addresses of the child devices after deciding the station numbers of the connected Modbus devices as described in the above "2) The number of devices to be connected". Those child devices not connected to the Modbus devices (repeaters) are not required to have station numbers. Set their addresses arbitrarily within the range of 4096 (0x1000) to 65533 (0xFFFC) so as not to overlap with those of other child devices.

7.1.11 EXAMINING PACKET FILTERING SETTINGS

Enable packet filtering to operate a system where an upper device polls transparent models and overlapped or delayed packets in the wireless network are discarded.

[Table 7.14] Packet filtering settings

ITEM	PARENT	CHILD	EXPLANATIONS
Packet filtering *1	Required	Required	Enable (Yes) or disable (None) the packet filtering function. When enabled, delayed packets, etc. are discarded according to the filter time-out on polling.
Filter timeout on polling, parent device *2	Required	–	Setting required when the packet filtering is enabled. Set a value subtracting the fixed overhead (1 sec.) from the valid polling time of an upper device (e.g. data acquisition device). Range: 10 – 600 (100 msec. increments)
Filter timeout on polling, child device *2	–	Required	Set a value greater than the polling response time. Range: 10 – 600 (100 msec. increments)

*1. Set to 'None' so as not to operate in a polling system.
   The setting must be identical in the same network.

*2. Timeout period must be longer for the upper devices (parent device) than lower devices (child devices).

7.1.12 EXAMINING FIXED ROUTE SETTINGS

In joining a network, a wireless device attempts to connect to a device with the highest RSSI value among the devices with the same PAN ID as explained in "7.1.2 PAN ID (GROUP NUMBER)" on page 54.

However, the fixed route function enables a device to connect with a specified destination regardless of momentary RSSI values.

In addition, the temporary detour function enables a device to transmit data via the detour when the radio wave status to the fixed destination is poor.

When the device fails to transmit data to the fixed destination, it retransmits data via a detouring route, if any.

Detouring three times switches the route to this detouring route temporarily even if the fixed route is available.

The registered fixed route is adopted again when it is re-established (in several tens of seconds to several minutes).

Specify a wireless device which is one-hop upstream as a fixed destination.

The downstream route is calculated automatically.

Consider use of this function when building a network in an environment where the radio wave state is unstable.

[Table 7.15] Fixed route settings

ITEM	PARENT	CHILD	REMARKS
Fixed route	–	Required	Enable (Yes) or disable (No) the fixed route.
Destination short address	–	Required	Short address of the fixed destination
Temporary detour	–	Δ	Enable (Yes) or disable (No) the temporary detour when the fixed route is enabled. *1

Δ: The value can be left at default.

*1. When a wireless device joins the network, unless the device receives the radio wave from the fixed destination, the participation in the network is not allowed even when the temporary detour is enabled.

7.1.13 NETWORK SCALE AND QUALITY SETTINGS

The transmission frequency of control signals to maintain a wireless network is optimized according to the number of wireless devices connected to the network.

Set the same device type and the number of devices to the wireless devices of the same PAN ID (group number).

The default is child (fixed), 1 to 30 devices. Select appropriate one in configuring the system.

When the actual device type or number is different from the setting, a malfunction such as data omission and separation of a child device from the network may occur, and also it may take longer time to detect the separation.

When the network quality is set to 'highest frequency of route switching and delay', the packet arrival rate is improved.

However, the frequency of retransmission becomes also higher than 'standard' to improve the reachability and the arrival (delay) time of data tends to be longer.

Set the network quality to 'standard' to keep balance of the data arrival time and the delay time, and to 'higher' or 'highest' to emphasize the arrival time.

[Table 7.16] Network scale settings

ITEM	PARENT	CHILD	SPECIFICATIONS / RANGE	REMARKS
Device type in a network, Number of devices in a network	Required	Required	Child (fixed), 1 to 30 devices Child (fixed), 31 to 60 devices Child (fixed), 61 to 100 devices Child (fixed) + child (moving)	Default: child (fixed), 1 to 30 devices Note: Do not select "child (fixed) + child (moving)" in connecting with V3.1.3 devices.
Number of child devices and wireless environmental sensors	Not required	Not required	Fast join mode: child devices only (25 child devices, 0 sensor) V3-compatible mode: standard (15 child devices, 10 sensors)	Fixed value Note: 'Standard (15 child devices, 10 sensors)' in connecting with V3.1.3 devices.
Network quality	Required	Required	Standard (recommended) Frequency of route switching and delay (higher) Frequency of route switching and delay (highest)	Default: standard (recommended) Note: Select 'standard (recommended)' in connecting with V3.1.3 devices.

* When wireless devices are used in low-speed moving devices

Data collection and control of moving child devices (4 km or less per hour) is pos

sible when the parent and child devices are set to 'low speed moving mode'.

The low speed moving mode can be used in the configuration consisting of a parent device, repeaters and the low-speed moving child devices.

The moving child devices do not have a relay function.

While moving, they switch the destination among the parent device and repeaters which is in an appropriate radio wave environment. One network contains up to 50 repeaters and moving child devices.

It is premised that the parent device and repeaters are not powered off, and the radio wave from them reaches the ranges where the child devices move.

In case of the parent device powered off/on after the network configuration, it may take maximum 1 hour to restore the network.

7.1.14 PASSWORD TO CONNECT DEVICE

A password to login from the maintenance console for a wireless device is configurable. For security reasons, it is highly recommended to change the factory setting to new one. The specifications of the password are as shown in the table below.

[Table 7.17] Login password

ITEM	PARENT	CHILD	SPECIFICATIONS / RANGE	REMARKS
Password	Required	Required	5 to 8 English one-byte characters	Case-sensitive

7.1.15 SIMPLE CALCULATION OF SAMPLING CYCLE

This section describes how to calculate sampling cycle in using wireless devices.

The values here are approximate, and may greatly vary depending on the radio wave environment.

With the model configuration in Figure 7.2 as an example, the conditions and Equation to calculate the sampling cycle for a data acquisition device to collect data from sensors are shown below.

The command response time is calculated with considering only the sensors connected to child devices.

Retransmissions of collect data commands due to timeouts, etc. are not considered in this calculation.

■ CALCULATION CONDITIONS

[Table 7.18] Calculation conditions

ITEM	VALUE (UNIT)	REMARKS
Reference command response time based on transmission data size	161 (msec.)	Refer to the response time for 1 point Input Register (3X)/Holding Register (4X) in Table 7.20 "Ready reckoner for command response time."
Delay time per hop	80 (msec.)	

■ EQUATION

Rough indication of command response time of child device

= (reference command response time + delay time per hop × (number of hops* − 1)) × No. of times of access.................Equation 7.1

* Number of hops = number of repeaters (child devices excluding low-speed moving devices) to pass through.
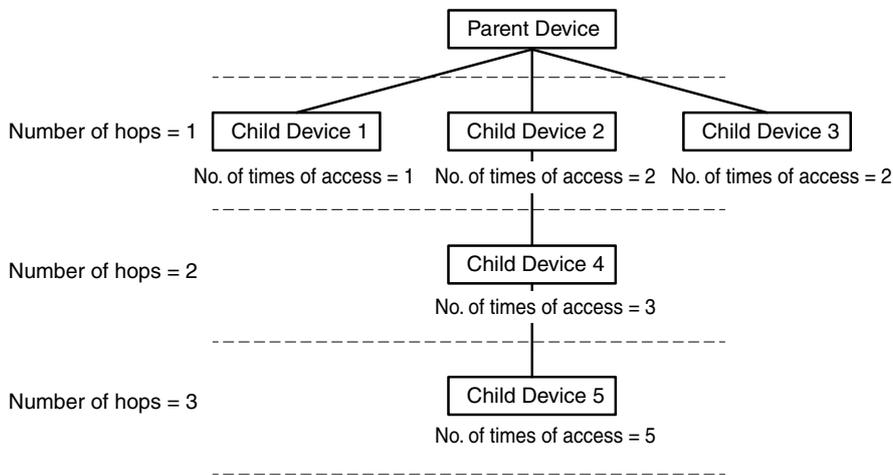
Figure 7.2 Model configuration for calculation of command response time

The table below shows command response time per child device in turning this model configuration into the Equation 7.1.

[Table 7.19] Command response time per child device in the model configuration

DEVICE	RESPONSE TIME (ms)	NUMBER OF HOPS	NO. OF TIMES OF ACCESS	COMMAND RESPONSE TIME PER DEVICE	COMMAND RESPONSE TIME (ms)
Child device 1	161	1	1	(161 + 80 × (1 − 1)) × 1	161
Child device 2		1	2	(161 + 80 × (1 − 1)) × 2	322
Child device 3		1	2	(161 + 80 × (1 − 1)) × 2	322
Child device 4		2	3	(161 + 80 × (2 − 1)) × 3	723
Child device 5		3	5	(161 + 80 × (3 − 1)) × 5	1605

The sampling cycle of data from the sensors connected to Child devices 1 to 5 is calculated as follows:

Sampling cycle = 161 + 322 + 322 + 723 + 1605 = 3133 (msec.)

Therefore, the sampling cycle must to be set to 3133 (msec.) or longer.

The table below is a ready reckoner for command response time used in the above calculation.

[Table 7.20] Ready reckoner for command response time

Coil (0X)/Input (1X) (bit unit)

Number of points	1	200	400	600	800	1000
Response time (ms)	148	182	195	224	240	257

Input Register (3X)/Holding Register (4X) (word unit)

Number of points	1	20	40	60	80	100	120
Response time (ms)	161	177	211	240	267	303	332

8. SETTING WIRELESS DEVICES

8.1 PARENT DEVICE

Refer to the manual as shown in the table below for the configuration of the parent device.

[Table 8.1] Configuration of parent device

MODEL	MANUAL
WL40EW2TW	WL40EW2x Operating Manual (EM-9115-B)

8.2 CHILD DEVICE

Refer to the manual as shown in the table below for the configuration of the child devices.

[Table 8.2] Configuration of child device

MODEL	MANUAL
WL40MW1TW	W920FCFG Users Manual (EM-9082)

9.   INSTALLING WIRELESS DEVICES

Carefully read through the following notes before installing wireless devices.

9.1   RECOMMENDED INSTALLATION LOCATIONS

In order to realize data communication in satisfactory radio wave conditions, wireless devices shall be installed under the following conditions.
1)   Install devices as high as possible to avoid obstacles that interrupt radio wave.
2)   When a metal plate is present behind a wireless device, the backward radio wave from the device may possibly become a noise reverberatively or hardly reach other devices installed behind. Avoid such a location as much as possible. When it is unavoidable, install an antenna as far from the metal plate as possible.
3)   Install wireless devices in unfrequented places with good visibility.

9.2   INSTALLING ANTENNAS

The radio wave state may vary greatly depending on the directions and installation locations of antennas. When it is poor, change their directions and locations as shown below.
1)   Match the polarization planes of a parent and child devices. Install an antenna with its direction perpendicular to the ground because its directionality is omnidirectional to the horizontal plane.
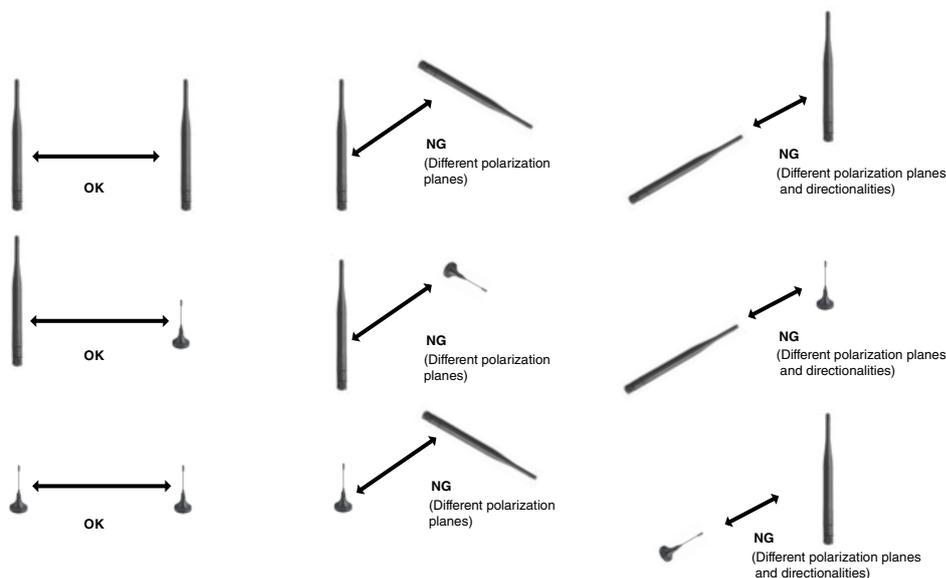
Figure 9.1 Polarization plane of antenna

2)   Secure a Fresnel zone.
3)   A sleeve antenna is movable in the range of 90°. Adjust the installing direction of the antenna and its angle. When changing the angle, turn the antenna clockwisely so that the antenna will not slip off or be loosened.
4)   In case of a rooftop antenna, extend a cable (2.5 m) to change the installation location of the antenna.
5)   When using a rooftop antenna, fix the magnet base to a metal plate (recommended dimensions: 500 mm × 500 mm or more).
6)   Make sure that there is no antenna used in a different network in the neighborhood. If any, secure the distance of at least 2 m or more away from such an antenna.

Note: When using a rooftop antenna, do not force the cable to bend beyond the acceptable bending radius of 3 cm.

9.3 DIRECTIONALITY AND POLIRIZATION PLANE OF ANTENNA

An antenna has a direction where it readily transmits or receives radio wave, which is called directionality.

The directionality depends on antenna types.

■ SLEEVE ANTENNA FOR WIRELESS I/O WL40TW SERIES

The following figures show the directionality of the sleeve antenna.

The sleeve antenna is omnidirectional in a horizontal plane.
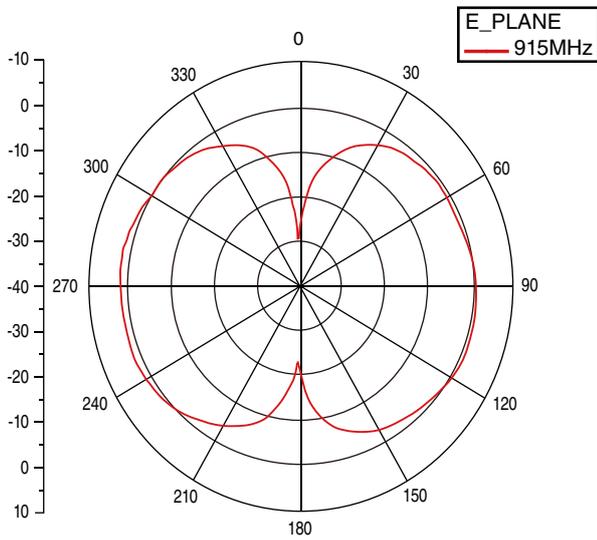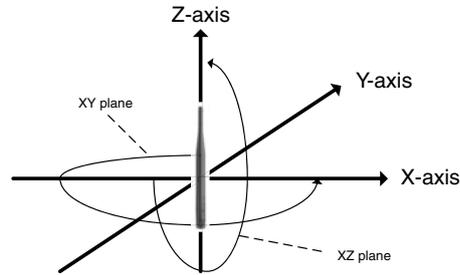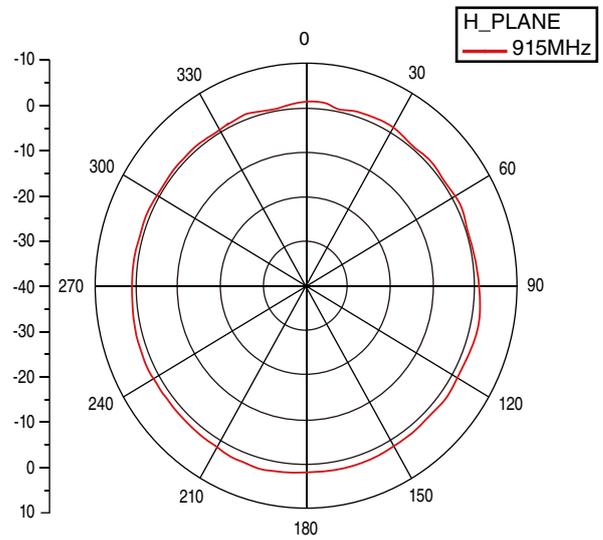
[E-Plane]　　　　　　　　　　　　　　　　**[H-Plane]**

Figure 9.2 Directionality of sleeve antenna for WL40TW series <reference>

■ ROOFTOP ANTENNA FOR WIRELESS I/O WL40TW SERIES

The following figures show directionality of the rooftop antenna.

The Rooftop antenna is omnidirectional in a horizontal plane.

[E-Plane]   [H-Plane]
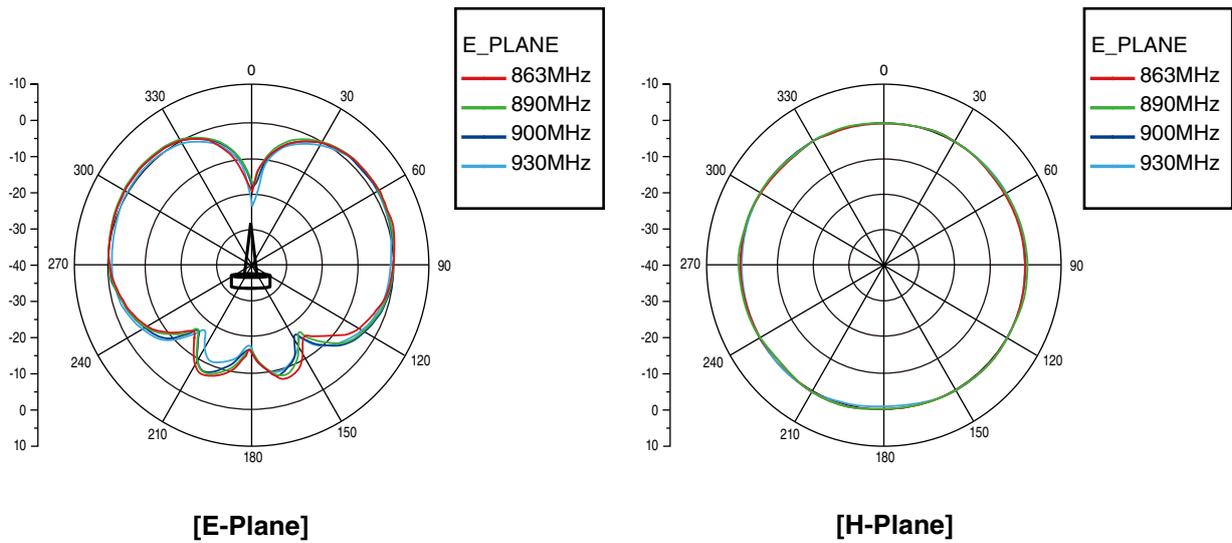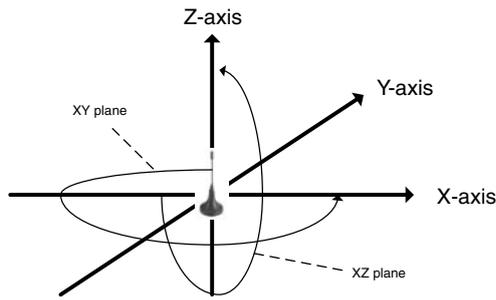
Figure 9.3 Directionality of rooftop antenna for WL40TW series <reference>

9.4 FRESNEL ZONE

A constant space is necessary for optimum receiving sensitivity of radio wave. This space is called Fresnel zone. When the Fresnel zone is secured, the distance causes attenuation of radio wave (free space propagation loss). To secure the Fresnel zone, install antennas more highly than the Fresnel radius with no obstacles (actually at least 60% clear of obstacles) between them as shown in "Figure 9.4 Fresnel zone".
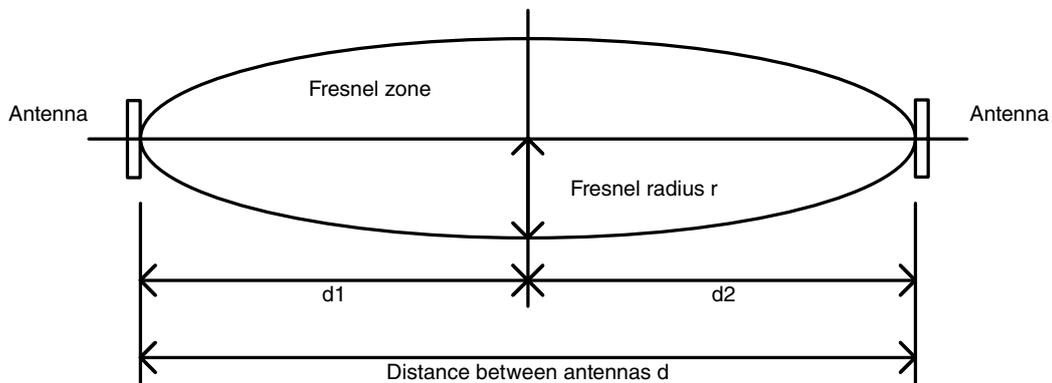
Figure 9.4 Fresnel zone

The Fresnel radius r can be obtained by the following formula:

$$r = \sqrt{\lambda \times \frac{(d1 \times d2)}{(d1 + d2)}} \qquad \text{Formula 9.1}$$

where r: Fresnel radius [m]
λ: wavelength [m]
d, d1, d2: distance between antennas [m]

The wavelength in 920 MHz is 0.326 m. The Fresnel radius is obtained by Equation 9.1 as shown in Table 9.1 when the antenna distance is 100 m, 200 m, 300 m, 500 m and 1000 m.

[Table 9.1] Fresnel radius

Distance between antennas	100 m	200 m	300 m	500 m	1000 m
Fresnel radius	2.85 m	4.04 m	4.94 m	6.33 m	9.03 m

The above table shows theoretical calculated values to obtain the Fresnel radius. Such a height is not always necessary for the radio wave to reach.

It is very difficult to secure the Fresnel radius for indoor use. Furthermore, indoor radio wave reaches a receiver through various routes, for example reaching directly a receiver antenna from a sender antenna, reaching after being reflected by walls, a floor, and a ceiling, and reaching by coming around obstacles such as partitions. Therefore, actual reception state cannot be shown in the same manner as a case where the Fresnel zone is secured. For indoor use, measure radio wave in each installing location in advance to check the reachability of the radio wave, and determine feasibility of installation.

9.5 INTERFERENCE TO RADIO WAVES

(1) NATURAL NOISES CAUSED BY LIGHTNING, STATIC ELECTRICITY, OR SOLAR RADIATION
- Noise caused by lightning may affect radio communications.
- Because of radio property, rain has little influence on radio communications.

  However, radio reachability can be affected when a water layer is formed by rainwater or snow accumulated on the metal plate surface to which the rooftop antenna is attached.

(2) RADIO WAVE INTERFERENCE
- Interference from a third party:

  Reception sensitivity may be deteriorated or interference may occur due to radio waves emitted from third party wireless devices.

  For example, radio interference may occur when other wireless devices using the same radio frequencies are present in the vicinity.
- Self-interference (multipath fading):

  Radio propagation path (diffracted wave, reflected wave, transparent wave) can affect radio communication.

  Radio wave can travel directly to a receiver but often reaches the receiver after being reflected by surrounding objects.

  So-called 'multipath fading' occurs when radio waves which have arrived at the receiver through respective paths interfere with each other, resulting in affecting the reception level of the radio waves.

  'Fading' is a phenomenon in which the reception level varies due to movement of a wireless device and/or with time.

(3) INFLUENCE OF OBSTACLES
- Radio wave status can change significantly due to the location of antenna within the installation site and objects in the vicinity which may shield radio waves.
- Radio wave transmission/reception environment may change due to new obstacles (trees, constructions, etc.) which were not present when wireless devices were initially installed.

(4) SPURIOUS RADIATION FROM ELECTRONIC EQUIPMENT
- A source of electromagnetic waves or magnetized object in the vicinity can cause noise and may affect radio communication

10. MEASUREMENT OF RADIO WAVE ENVIRONMENT

Perform the measurements described in "6. PRELIMINARY MEASUREMENT OF RADIO WAVE ENVIRONMENT" again with the installed wireless devices.