Technical Information

TI 01W01A51-12EN

Guidelines
for Layout and Installation
of Field Wireless Devices

ISA100 Wireless COMPLIANT

Contents

YOKOGAWA ◆

Yokogawa Electric Corporation
2-9-32, Nakacho, Musashino-shi, Tokyo, 180-8750 Japan
Tel.: 81-422-52-5634 Fax.: 81-422-52-9802

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Introduction

This guideline explains how to install field wireless devices in a system with the YFGW410 field wireless management station and YFGW510 field wireless access point, and how to determine whether actual communication tests are needed. Layout examples that comply with the guidelines are also shown.

The following symbols are used in the product and user's manual to indicate safety precautions:

CAUTION

This symbol indicates cautions required when handling the product. This symbol is placed on parts of the product requiring reference to the user's manual to protect the operator and the product itself. In the user's manual, this symbol is accompanied by precautions to avoid physical injury or death of the operator, including electrical shocks, injury, and others.

WARNING

This symbol indicates instructions that must be observed to prevent the software or hardware from being damaged or the system from becoming faulty.

IMPORTANT

This symbol indicates important information required to understand operations or functions.

Revision Information

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Edition	Date	Page	Revised Item
1st	August 2013		New Issue

Terms and definitions

● **Visual assessment**

A visual assessment involves visually evaluating the site to check the line-of-sight of wireless communication paths, how to install wireless transmitters, how to feed power to access points, and how to layout the communication paths to the upper system.

● **Site survey**

A site survey is an actual communication test with equipment at proposed installation points to check the reliability of wireless communication paths.

● **Access point (AP)**

In this document, the YFGW510 field wireless access point is referred to as an access point (AP).

● **Router (RT)**

In this document, a device that relays wireless communication is referred to as a router (RT).

Overview

Yokogawa's field wireless system conforming to the ISA100.11a standard features a long communication distance with low error rate and high receiver sensitivity. The system is designed for customers who require reliability, performance, and future innovation. To make full use of field wireless devices, the optimal installation layout is required.

Although conditions at installation sites differ from place to place, a study of the site plan/device layout or visual assessment is usually enough to ensure a successful installation. These assessments assure efficient network design and reliable communications. However, an actual communication test is recommended to confirm the reliability of communication paths and to find the optimum layout in harsh environments for wireless signals.

Communication distance is a key indicator of the performance of wireless devices. Wireless devices with longer communication distance usually have higher performance. Wireless communication distance is evaluated with the packet error rate (PER). Under ideal circumstances, the PER correlates directly with the receiving signal strength indicator (RSSI), and thus the PER can be predicted from the value of RSSI. However, RSSI correlates poorly with PER in a place surrounded by metal structures because of multipath fading and obstacles. Therefore, Yokogawa directly uses the PER as an evaluation parameter.

The field wireless system re-sends packets when wireless communication fails. If the PER is high, the system repeatedly sends lost packets, which delays the data from wireless transmitters reaching the upper system. In addition, wireless signals are often reflected off many metal structures in a plant, causing the PER to become unstable, and the degree of delay to fluctuate. With a long delay, the system may not satisfy required data update cycles. In particular, the delay becomes worse in a system with a high PER in a mesh topology which uses routers (see Part B).

Laying out field wireless devices as described in this document will help suppress the increase in PER even in harsh environments, and stabilize wireless communication.

Part A explains the basic wireless connection topology. Part B describes how to install field wireless devices. Part C shows the evaluation procedure in site surveys, and Part D and E show examples of judging the necessity of site surveys.

Part A. Layout and Topology of Wireless Devices

To enable widespread usage, Yokogawa's field wireless system supports two network topologies: star topology and mesh topology.

The topology and layout are closely related. The star topology is used when the sampling interval is less than 5 seconds. The mesh topology is used for a sampling interval of 5 seconds or longer because transmission may be delayed due to the multi-hop configuration.

Basically, devices are laid out as follows:

A1. Star topology

In the star topology, an access point communicates with multiple wireless transmitters directly. Therefore, these devices or their antennas must be installed to secure the line-of-sight and Fresnel zone (see Reference 2). In Class A and B areas (see Section B1.1), it is crucial to secure the line-of-sight.

In Class C areas, on the other hand, the line-of-sight may not matter because of the short wireless communication distance. The maximum communication distance can be extended by avoiding obstacles with remote antennas or by using high-gain antennas.

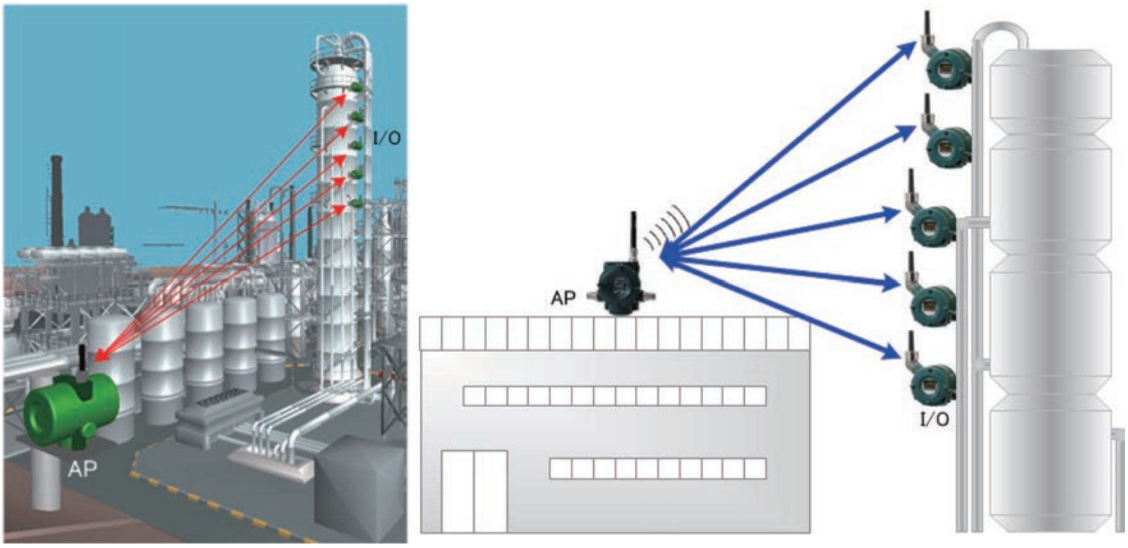


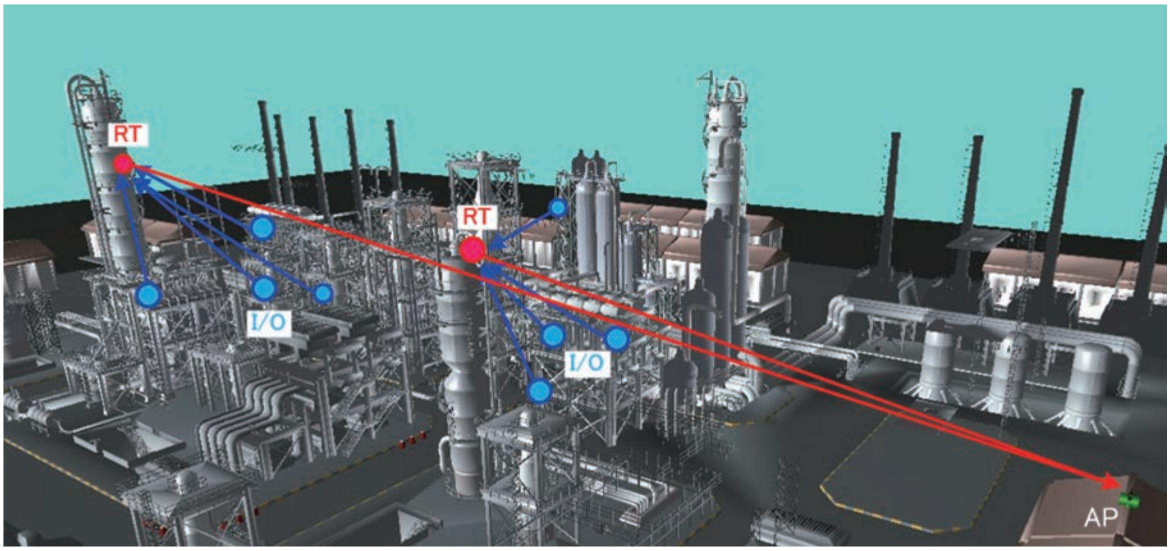
Figure A-1 Star topology

A2. Mesh topology

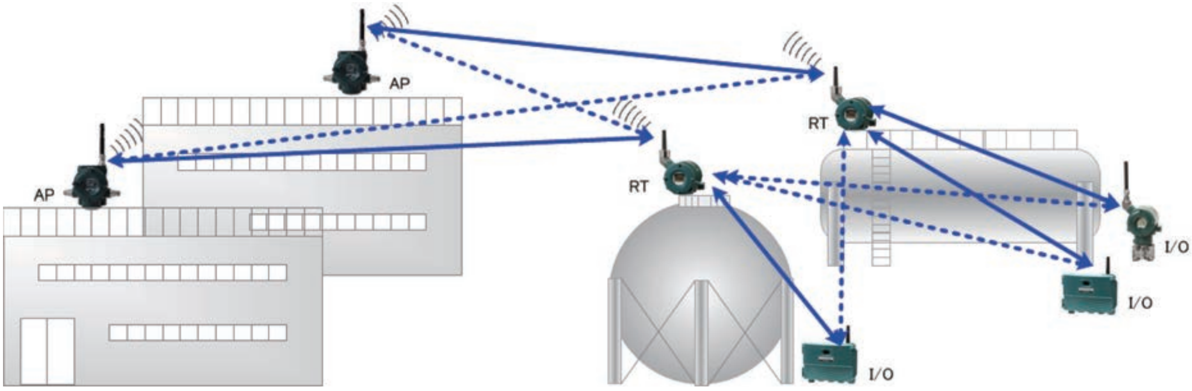
Yokogawa's field wireless network supports up to four hops for the mesh topology. The mesh topology assures scalability and connectivity by installing routers sufficiently high to give a clear line-of-sight. The mesh topology is used for securing redundancy or avoiding obstacles.

As a general rule, Yokogawa's field wireless devices are installed within two hops as shown in Figure A-2. Routers are installed high up over the plant. Yokogawa calls this form Sky Mesh. Note that if the number of hops increases, the device layout and installation design will become complicated, which limits the number of devices that can be connected to the routers. A three- or four-hop configuration should be used only where communication devices are arranged in a line such as off-site of wellheads.

Routers or their antennas are installed at heights to secure the Fresnel zone depending on the communication distance between routers and an access point (described later). This can reduce the influence of obstacles such as fixed facilities and devices, as well as the effect of moving obstacles such as large vehicles or crane trucks.



(a) Sky Mesh in a plant



(b) Mesh topology for a redundant path network

Figure A-2 Mesh topology

Part B. Guidelines for Device Layout and Installation

There are three guidelines for the layout of field wireless devices: communication distance, installation procedure, and use of routers.

B1. Communication distance

Yokogawa's field wireless devices conforming to the ISA100.11a standard feature a long communication distance. The data in this section are based on Yokogawa's field wireless devices only.

B1.1 Classification of communication environment and expected communication distance

To facilitate the layout and installation of field wireless devices, Yokogawa classifies the expected communication distance into three classes according to the communication environment. The expected communication distance is measured with a 2 dBi antenna with all installation requirements satisfied (including the gain of an antenna with output of 10 mW).

1. Free space (Class A): Area with no obstacles around wireless devices

Expected communication distance: up to 500 m

Examples: Pipeline, tank yard

Figure B-1 Example of Class A area

2. Minor obstacles (Class B): Area with structures and obstacles which affect wireless signals through reflection, etc.

Expected communication distance: up to 200 m

Examples: Areas with buildings or machines around the communication path. Areas with dense piping along the communication path.

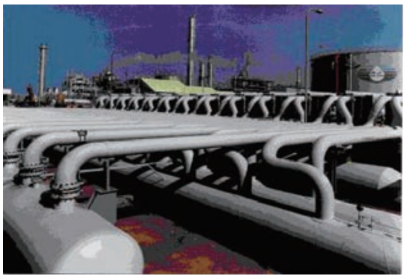


Figure B-2 Example of Class B area

3. Dense obstacles (Class C): Area surrounded by structures and obstacles which severely affect wireless signals.

Expected communication distance: up to 50 m

Examples of area: Inside of the plant surrounded by pipes and machines

Figure B-3 Example of Class C area

B2. Installation procedure

This section outlines the usage criteria for routers, high-gain antennas, and extension antenna cables. There are two general rules about the installation regardless of whether or not to use these devices.

- **Up to two hops**

  As the number of hops increases, the number of transmitters connectable to each router decreases, which makes it difficult to lay out the system.

- **Installation at heights**

  Antennas should be installed at heights to avoid the influence of both fixed obstacles (buildings, etc.) and moving obstacles (vehicles, etc.) in a plant.

  Select an appropriate installation procedure depending on the requirements below:

Communication cycle of less than 5 seconds	→ Star topology
Sky Mesh Avoid obstacles/Extend distance	→ Mesh topology
Long-distance communication with multi-hops	→ Mesh topology with three or more hops
Other installation procedure: Avoid small obstacles Long-distance communication with one hop	→ Use of remote antennas → Use of high-gain antennas

Figure B-4 Selection of an installation procedure

B2.1 Selecting the star topology

When a communication cycle of less than 5 seconds is required, the star topology is recommended to be used for communication between transmitters and an access point. Even when there are obstacles in the line-of-sight, the star topology ensures communication as long as the communication distance is 50 m or shorter. This is because wireless devices can receive signals which are reflected off the surrounding piping or walls.

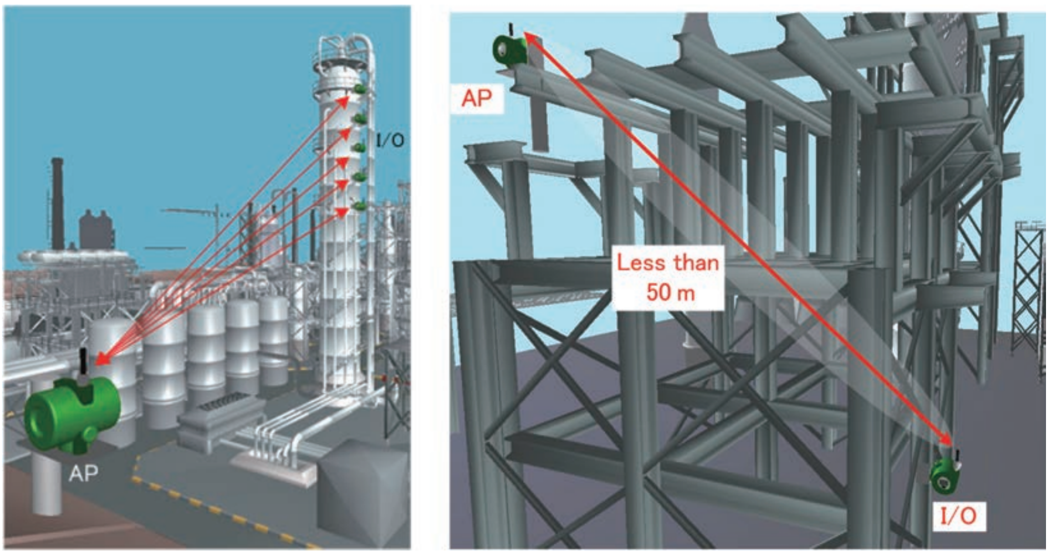
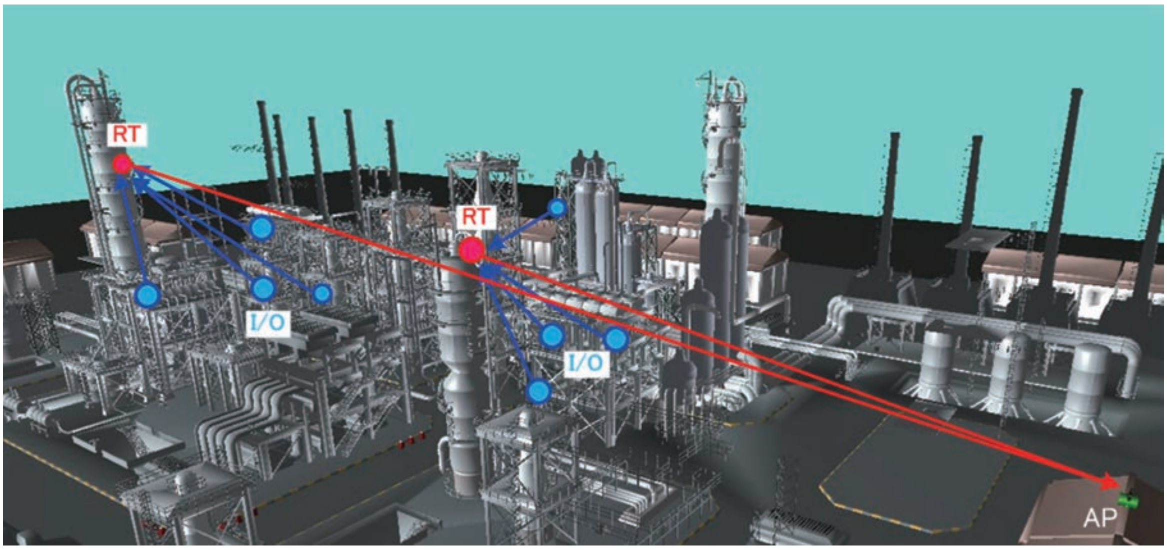


Figure B-5 Selecting the star topology

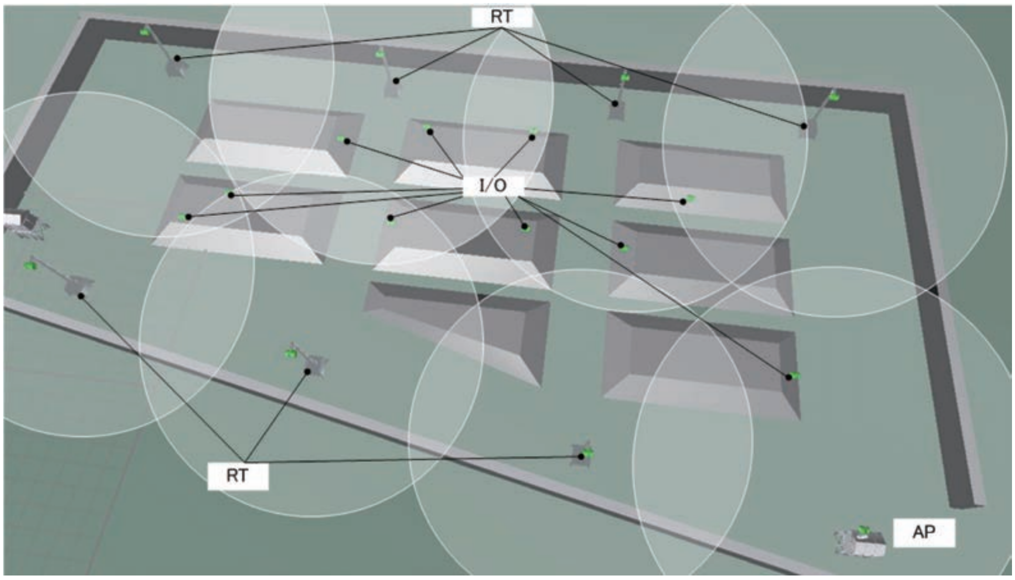
B2.2 Selecting the mesh topology

● **Sky Mesh in a plant**

As described earlier, routers at heights with a clear line-of-sight improve expandability and connectivity. Devices installed as shown in Figure B-6 (a) cover a wide area of communication. When routers are installed so as to overlap each other's communication area as shown in Figure B-6 (b), communication is maintained even if the measuring points move within a specified area such as coal storage yards.



(a) Sky Mesh configuration



(b) Coal storage yard

Figure B-6 Example of the mesh topology

● **Avoiding obstacles and extending the communication distance**

Installing routers in the mesh topology extends communication beyond the expected communication distance while avoiding obstacles*1. Routers and their antennas are installed so that the Fresnel zone is secured. Use 2-dBi standard antennas in consideration of their directivity angle*2. For details on installing routers, see the following section.

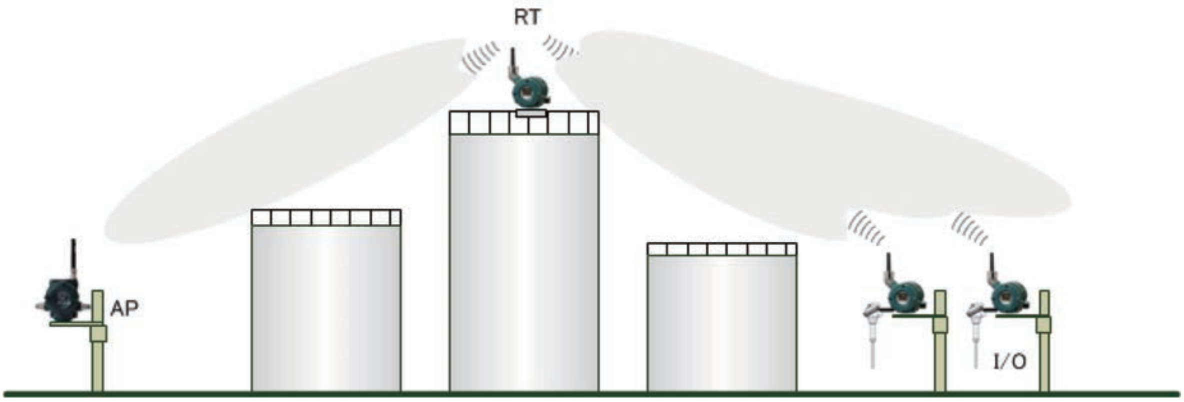


Figure B-7 Avoiding obstacles with the mesh topology

*1: Relatively small obstacles can be avoided by shifting antennas with extension antenna cables (up to 13 m) described later.
*2: For details of the directivity angle, see Reference 2.

B2.3 Configuring the mesh topology with three or more hops

The mesh topology is basically constructed with up to two hops, but it can be constructed with three or four hops where long-distance communication is required such as wellheads and offshore plants as long as routers can be installed in a line. In this case, the number of devices connectable to routers decreases. For details, see “G2.6.1 Restrictions on the Number of Connectable Devices by Network Resources” (IM 01W02D01-01EN).

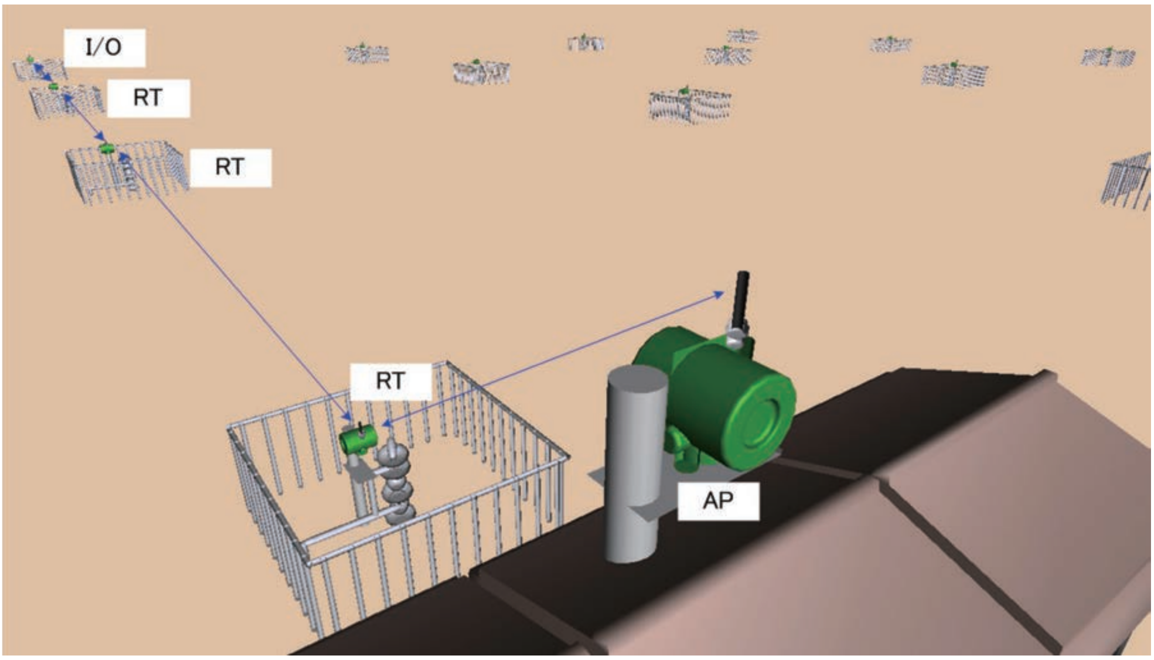


Figure B-8 Example of the mesh topology at a wellhead

B2.4 Other installation procedures: using high-gain antennas

With a high-gain antenna, longer communication than the expected communication distance is possible. In this case, the height of the antenna and the Fresnel zone must be considered as shown in Reference 1. Because high-gain antennas need a clear line-of-sight, they are not used in Class B and C areas.

● Order of priority when installing high-gain antennas

If the distance between wireless devices exceeds the maximum communication distance in the relevant class, use a high-gain antenna for access points. In this case, sufficient height is necessary to secure the Fresnel zone. For details, see Reference 1.

● Antenna height of the target device

When a high-gain antenna is used, the antenna height of the target device must be considered. The antenna of the target device must be within the radiation angle of the high-gain antenna.

Table B-3 shows the allowance of the antenna position of the target device (difference in height between the originating antenna and the destination antenna) when using a 6 dBi antenna as the originating antenna. In this case, the allowance is about one-fifth the communication distance.

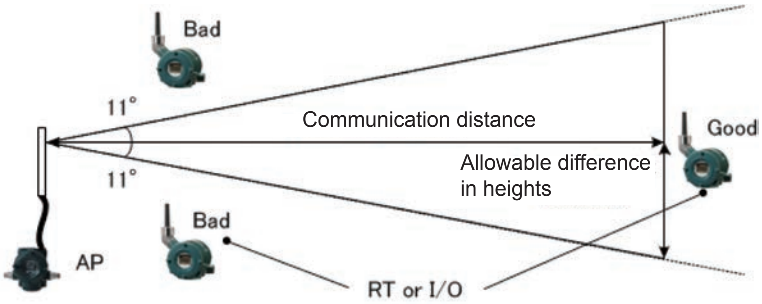


Figure B-10 Relationship between the communication distance and antenna height

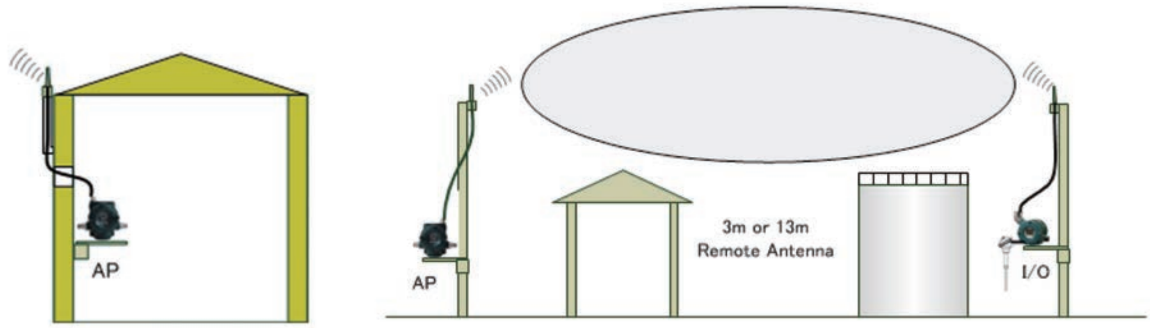
Table B-3 Correlation between communication distance and allowable antenna height

Communication distance (m)	Allowable antenna height [m]
10	2
50	10
100	20
200	40
500	100
800	156

*Note that there is no need to consider the allowable antenna height in long-distance communication. For a communication distance of 100 m or longer, a difference between antenna heights of 20 m or more is allowable. This guideline applies to cases where antenna heights are extremely different from each other..

B2.5 Other installation procedures: using extension antenna cables

To set up communication from inside a building to the outside or to avoid small obstacles, use a 3 m or 13 m extension antenna cable. Extension cables are often a useful way to secure an excellent line-of-sight.



(a) Installing an antenna outside the building **(b) Securing the Fresnel zone**

Figure B-11 Using an extension antenna cable

B3. Using routers

Follow the guidelines below when installing routers.

- Installing routers so that all transmitters have two communication paths.
- Install routers as high as possible.
- Use a 2 dBi antenna for routers which cover I/O devices located below.

B3.1 Installing routers so that all transmitters have two communication paths

If there is only one communication path and the router battery needs to be changed or a communication failure happens, the data from transmitters will be lost. Installing routers to secure at least two communication paths can significantly reduce the risk of data loss.

B3.2 Installing routers as high as possible

To secure communication quality between the router and an access point, install routers as high as possible with a clear line-of-sight to the access point. This minimizes disturbances caused by vehicles and humans and makes communication more reliable.

B3.3 Using a 2 dBi antenna for routers

Use a 2 dBi antenna for routers which cover I/O devices located below. This is because 2 dBi antennas have a wide directivity angle and are ideal for vertical communication (see Reference 2). With a good line-of-sight, 2 dBi antennas can communicate with the target device over a distance of up to 30 m even if it is located out of the radiation angle.

B3.4 Examples of router installation

Install routers so that a reliable communication path with few obstacles is secured.

(1) Secure a communication path above obstacles between the access point and the router.

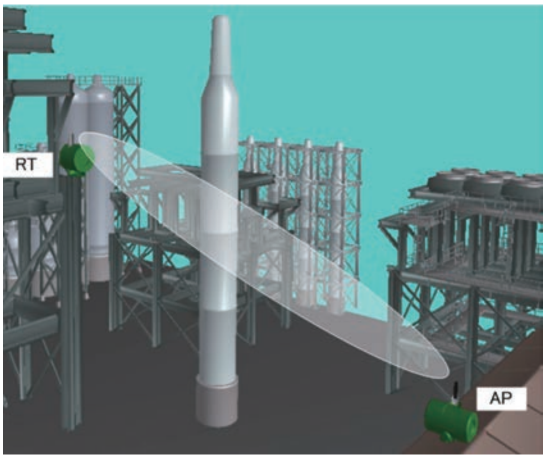


Figure B-12

(2) Secure vertical communication paths among the router and transmitters.

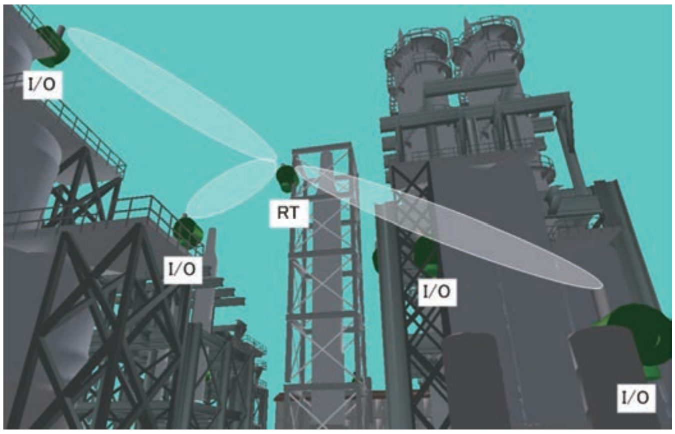


Figure B-13

(3) A poor line-of-sight does not affect communication between the router and transmitters as long as the communication distance is 50 m or shorter.

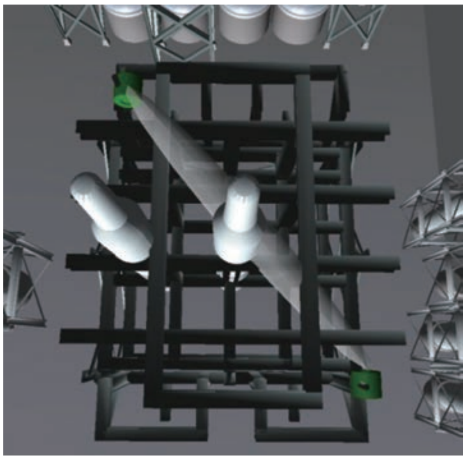


Figure B-14

Part C. Guidelines for Implementing the Site Survey

This section and the following sections describe the types of device layout. A layout with visual assessment alone and another one which needs a site survey are illustrated.

Visual assessment is necessary for confirming how to mount transmitters, how to feed power to the access point, and how to connect the upper system, and is almost the same as that for wired transmitters. When designing a field wireless network, the following additional information is needed: a site map, layout of other devices, and additional information to judge applicability to the design types described below.

If the feasibility of installation is still not clear, carry out a site survey.

C1. Installation design with a site plan/device layout only (visual assessment and site survey are not required)

This design is applicable when the following conditions are confirmed with the site plan:

Outdoor installation, topology with up to two hops, good line-of-sight, and sufficient height of antennas securing the Fresnel zone with no obstacles

C2. Installation design with a site plan/device layout and visual assessment (site survey is not required)

When the design follows the installation guidelines and there are no other 2.4 GHz networks (e.g., Wi-Fi), site surveys can be omitted.

The following two cases do not require a site survey:

1. Wireless devices are fixed in a room with an area of 50 m square or smaller. Wireless devices can be mounted on rotating objects but not on moving objects.
2. Wireless devices are mounted in a space with a metal grating floor, but the communication distance is 50 m or shorter.

C3. Installation design requiring a site survey

If the feasibility of installation is still not clear after the visual assessment and installation design, carry out a site survey.

The following cases clearly need site surveys:

1. Communication between indoors and outdoors. At least one wireless device is located in a shielded enclosure such as a basement or prefabricated building.
2. Wireless devices are mounted on moving objects.
3. There is another 2.4 GHz network (e.g., Wi-Fi) near the communication path.
4. There are noise sources near the communication path (e.g., military communication facilities and radars with high output power).

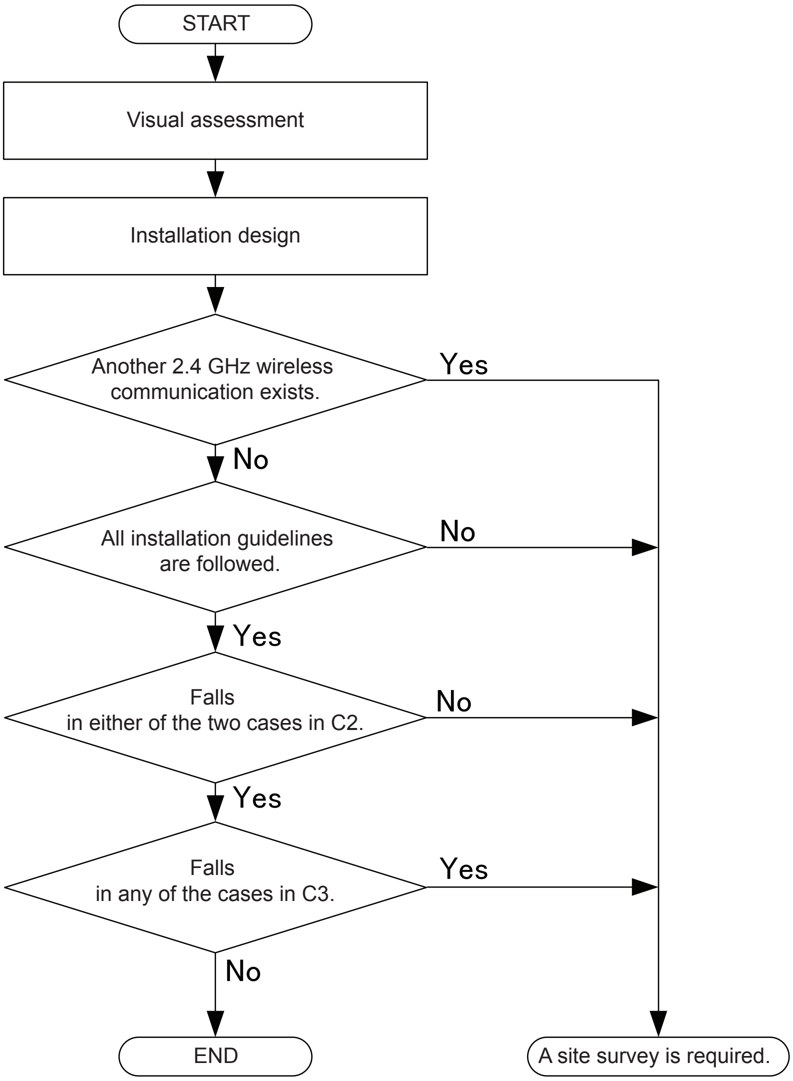


Figure C-1 Flow chart for judging the necessity of site surveys

Part D. Examples of Installation Design Not Requiring Site Surveys

D1. Installation guidelines are followed

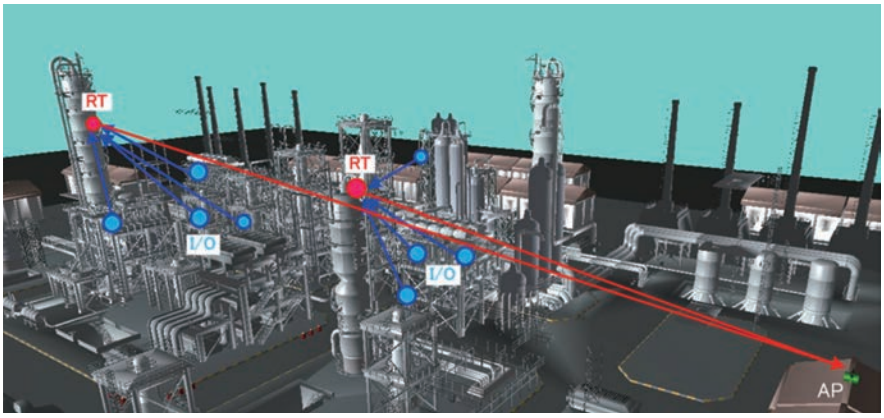


Figure D-1 Example of a layout following the guidelines

D2. Devices are mounted on rotating objects

The line-of-sight from transmitters mounted on rotating objects to an access point is periodically disturbed by the objects. However, communication can continue thanks to reflected signals. The area of the installation site, material of the walls, and other possible obstacles at the site must be surveyed.

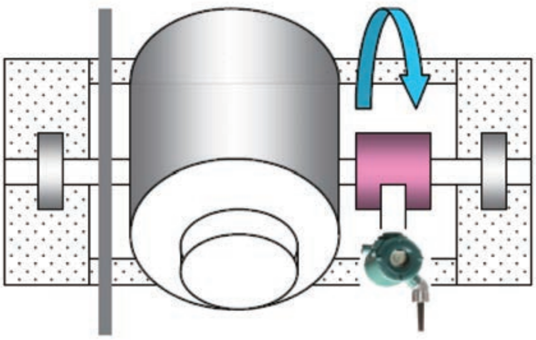


Figure D-2 Example of mounting on a rotating object (1)

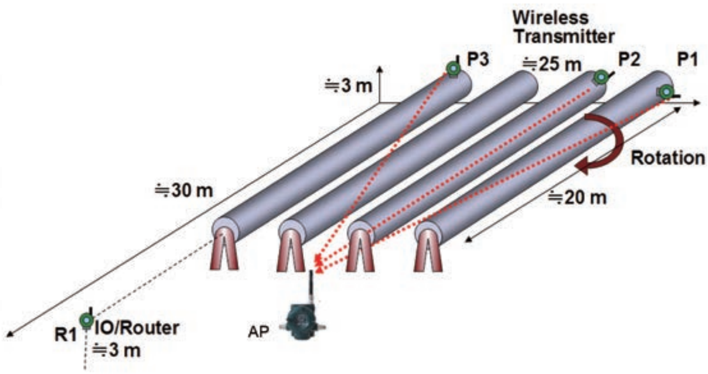


Figure D-3 Example of mounting on a rotating object (2)

D3. Devices are installed in a small space (50 m square or smaller)

Even with a poor line-of-sight or obstacles including metal grating floors, transmitters can maintain communication as long as the communication distance is 50 m or shorter.

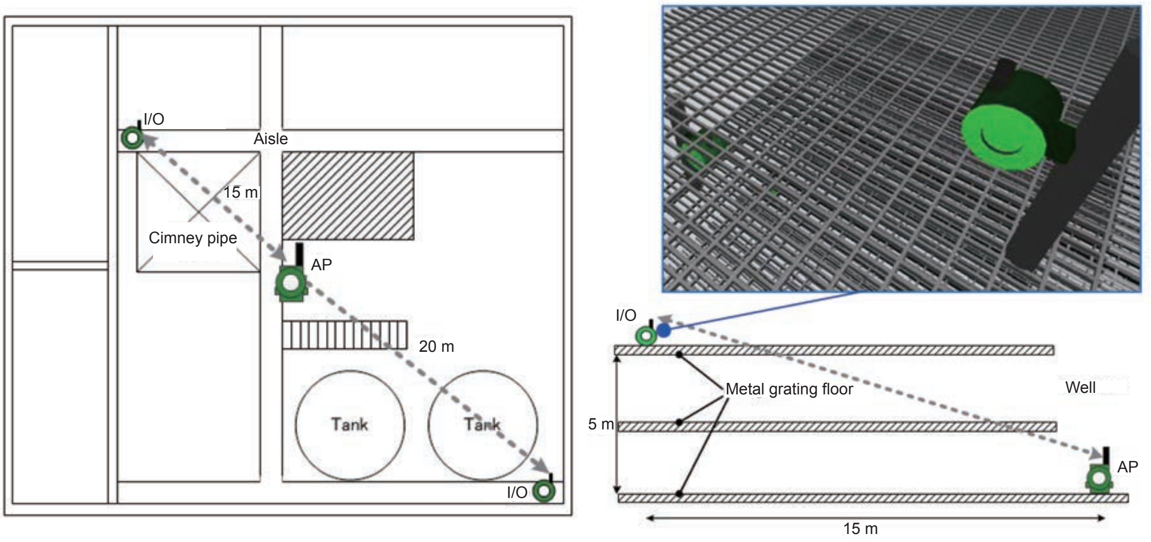


Figure D-4 Example of installation with obstacles and metal grating floors

Part E. Examples Clearly Requiring Site Surveys

E1. Installation in a place surrounded by metal walls

A site survey is required before installing transmitters in a place surrounded by metal walls. Possible routes of communication should be explored in the site survey because wireless signals cannot pass through metal walls. Wireless signals can communicate through non-metal walls, although the signals will be attenuated to some extent.

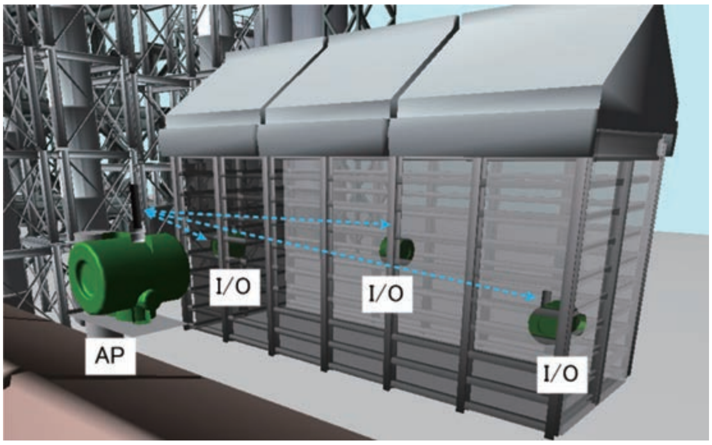


Figure E-1 Space surrounded by metal or concrete walls

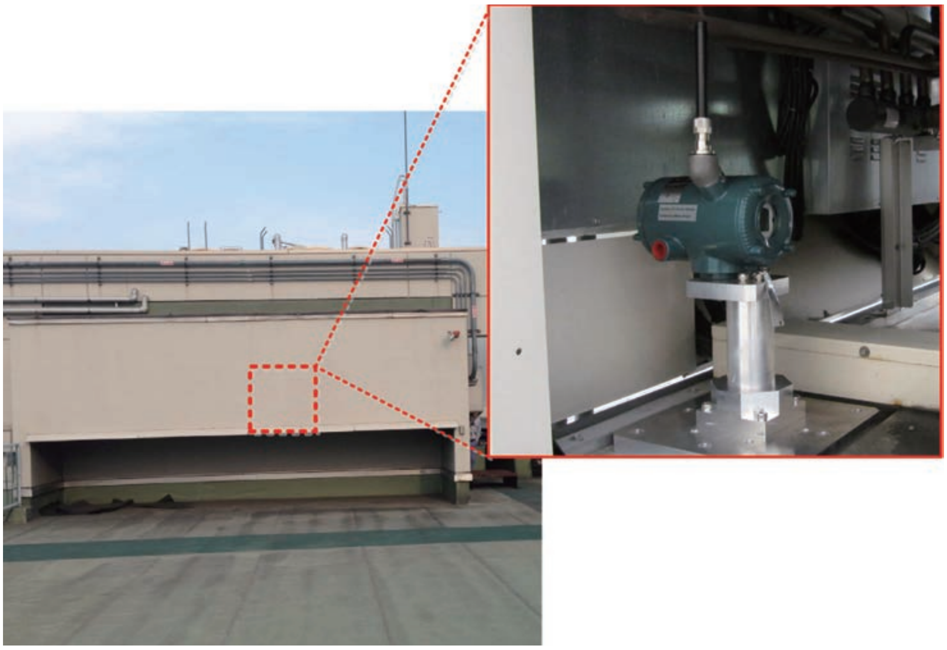


Figure E-2 A transmitter surrounded by metal walls

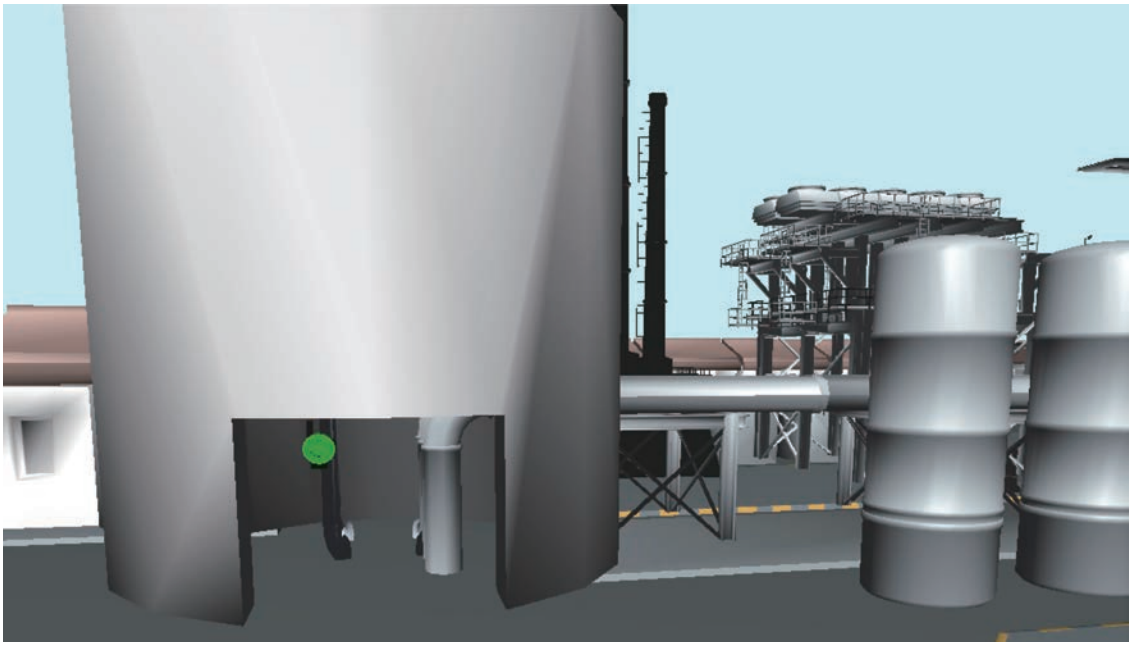
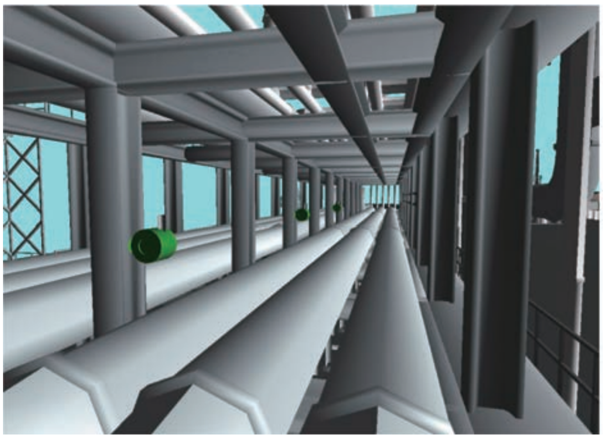
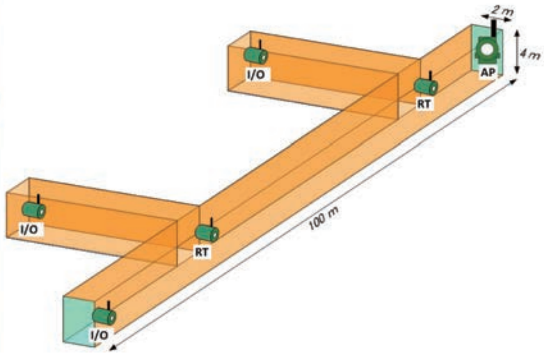


Figure E-3 A transmitter surrounded by concrete walls



(a) Installation in a pipe rack



(b) Installation in a tunnel

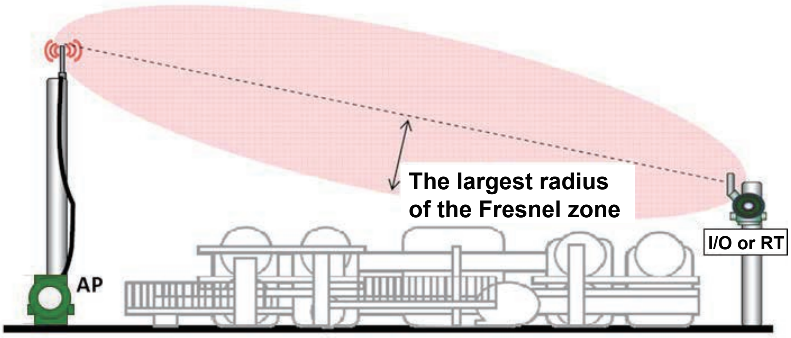
Figure E-4 Small installation area in which it is difficult to secure the Fresnel zone

E2. Wi-Fi communication close to the field wireless system

Please contact the nearest Yokogawa sales office or Yokogawa representative.

Reference 1: Fresnel Zone

For reliable wireless communication, it is important not only to secure the line-of-sight but also to ensure that there are no obstacles in the surrounding space. This space is called the Fresnel zone and is largest at the mid-point of the communication distance. The radius of the Fresnel zone depends on the communication distance.



Distance (m)	The largest radius of the Fresnel zone (m)
50	1.2
100	1.8
150	2.2
200	2.5
300	3.1
400	3.5
500	4.0
600	4.3

If there are any obstacles within the zone, the communication distance becomes shorter. The ground is also a possible obstacle. Therefore, when installing wireless devices, the effect of the ground can be expected even if there are no obstacles between them. Referring to the table above, wireless devices must be mounted higher than the largest radius of the Fresnel zone.

Maximum communication distance with an intact Fresnel zone

In order to estimate a communication distance for each path, the expected communication distance in respective environmental classifications (A, B, C) and obstacles in the Fresnel zone (see Reference 1) must be considered. The table below shows the expected communication distance in consideration of the factors.

Table Communication distance depending on factors

Combination of antennas	Antenna height (m)	Maximum communication distance		
		Class A (500 m)	Class B (200 m)	Class C (50 m)
2 dBi - 2 dBi	4.0	500	250	50
	3.1	300	150	
	1.8	100	50	
	0.5	—	50	
2 dBi - 6 dBi	5.5	1000	—	—
	5.0	800	—	—
	4.5	600	—	—
6 dBi - 6 dBi	7.5	1500	—	—
	6.5	1250	—	—
	5.5	1000	—	—

Even if a line-of-sight cannot be secured, good communication is expected in a Class C area as long as signals can reflect off surrounding structures (unless the wireless devices are enclosed by metal walls). For details, see B2.

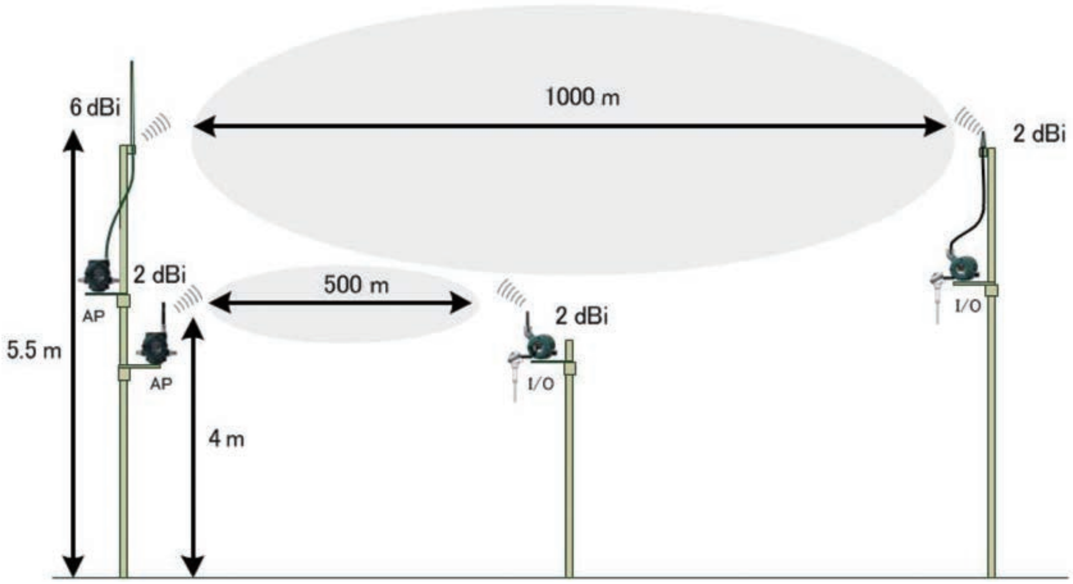


Figure Antenna height necessary for 500 m and 1000 m communication

Reference 2: Requirements for Antenna Installation

To satisfy the communication distance specification, antennas must be installed in compliance with the following conditions. Otherwise, communication distances may become shorter.

A. Field wireless devices must be mounted where no obstacles exist near their antenna.

B. Antennas must be installed vertically.

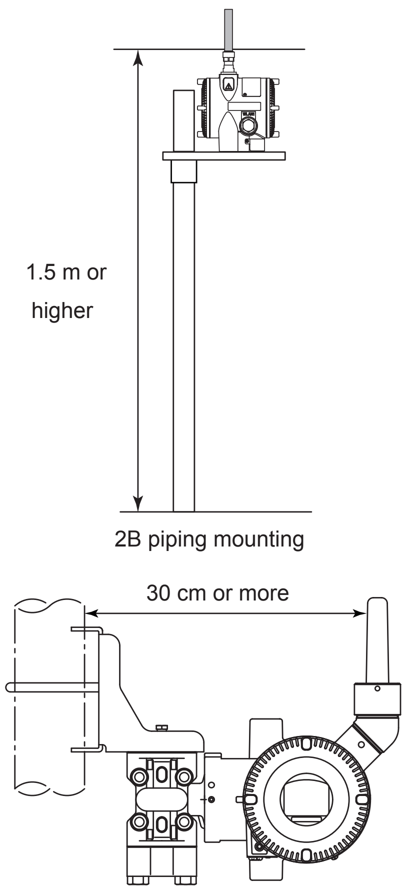
C. Antennas must be at least 30 cm* away from mounting piping or plumbing.

D. If the installation location is too close to walls, use a remote antenna and extension antenna cable to prevent obstacles from affecting wireless signals.

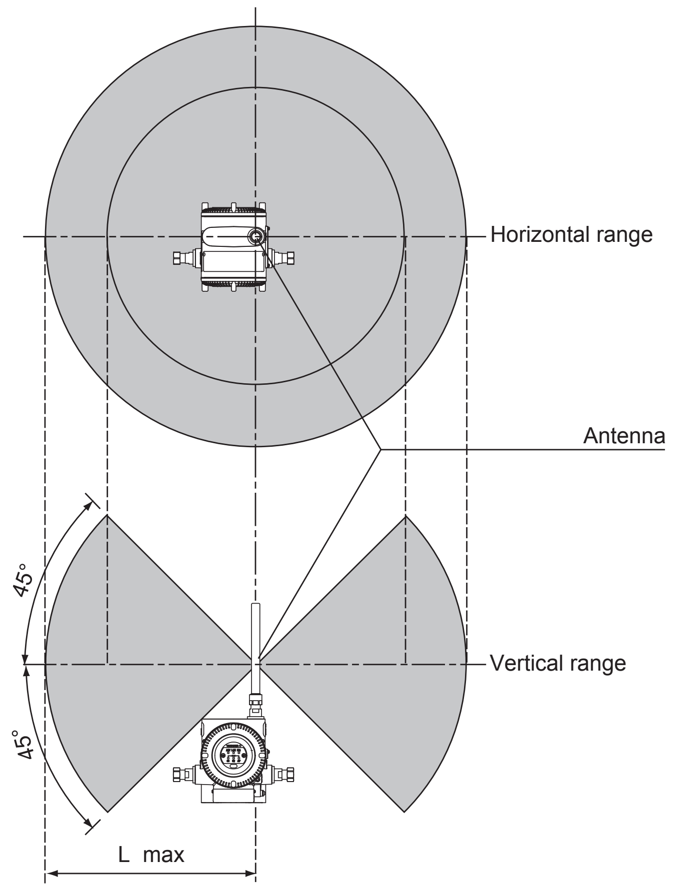
E. In Class A and B areas, install field wireless devices so that each has a good line-of-sight to other antennas in the communication area. Use a remote antenna and extension antenna cable, if necessary. This is not essential in a Class C area because it is difficult to secure a good line-of-sight only with extension antenna cables in such an area.

F. When devices are installed at different heights, overlap their communication ranges in consideration of the radiation characteristics of respective antennas. Thus, for example, standard 2 dBi antennas can emit signals up to 45 degrees up or down from the horizontal plane. Meanwhile, 6 dBi antennas emit only within ±11 degrees. So, 6 dBi antennas are not appropriate for vertical communication.

*When 2 dBi antennas are used in a Class C area
(When 2 dBi antennas are used in Class A or B areas, antennas must be at least 1 m away from mounting piping or plumbing.)



Requirements for mounting



Radio propagation area (standard antenna)

Reference 3: Packet Error Rate (PER)

The packet error rate (PER) is a good indicator to judge the reliability of communication paths. The PER equation is as follows:

PER (%) = Number of lost packets/Number of transmitted packets × 100

Packets are considered as lost when an “acknowledge” packet from the target device is not received or when a “no acknowledge” packet from the target device is received.

Yokogawa’s field wireless system re-sends packets when it detects packet loss. With a low PER, devices can successfully send all data with fewer retries.