Techniques for Enhancing the Reliability of Field Wireless Control Data Communication

Hitoshi Saito [*1]   *Naoyuki Fujimoto* [*1]

With the spread of field wireless devices complying with the ISA100.11a field wireless standard, there is a growing need to use them not only for process monitoring but also for process control, in which a host system wirelessly transmits control data to these devices. This paper describes the wireless transmission of control data and techniques for enhancing its reliability. As an example of products with field wireless control data communication, this paper introduces the FN910 module, which operates pneumatic valve actuators in accordance with wirelessly transmitted instructions.

INTRODUCTION

As the product range of wireless field instruments is enhanced, the introduction of wireless instrumentation is expanding applications to take advantage of its strength such as elimination of wiring work. In 2012, Yokogawa released the YFGW410 field wireless management station and YFGW510 field wireless access point, which offers highly reliable redundant wireless infrastructure [(1)]. The YFGW410 can transmit control data to wireless field instruments, expanding the use of field wireless for not only measurement but also control. Conventionally, when communication fails, transmission of control data is suspended for about 10 minutes to change the communication path. However, the new redundancy method, which eliminates the path change, secures real-time communication of control data and achieves highly reliable communication.

This paper describes a method to improve the reliability of communication for control data in field wireless systems, and introduces the FN910 field wireless solenoid-valve control module as an example that takes advantage of this method.

COMMUNICATION MECHANISMS IN FIELD WIRELESS SYSTEMS

To understand the new method for enhancing reliability of field wireless communication, this section describes the communication mechanisms in field wireless systems using the YFGW410 and YFGW510.

*1 Wireless Development Dept., New Field Development Center, IA Platform Business Headquarters

Control-data Communication and Sensor-data Communication

Wireless field instruments measuring process values, such as temperature transmitters, periodically transmit measured data to the access point (hereafter called “sensor-data communication”).

Meanwhile, wireless field instruments for controlling operation targets receive operation commands through communication for periodically receiving control data (hereafter called “control-data communication”), and send back the read-back values of operation commands through sensor-data communication. The host system sending operation commands confirms the successful arrival of operation commands by reading back values sent through sensor-data communication.

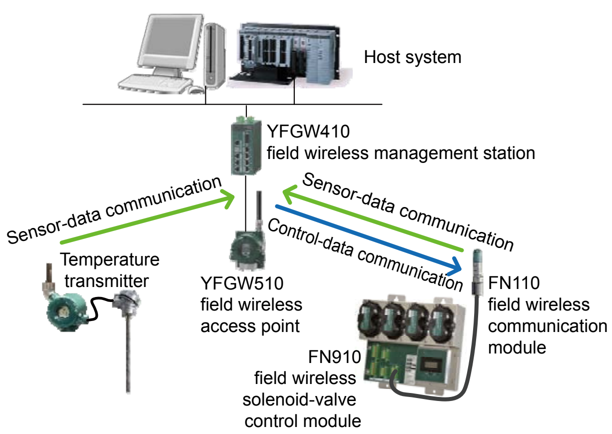

Figure 1 Sensor-data communication and control-data communication

Figure 1 shows how the sensor-data communication and control-data communication are performed. The FN910 works in combination with the FN110 field wireless communication module [2] (hereafter, "FN910" denotes both FN110 and FN910).

Data Update Cycle

In control-data and sensor-data communication, data are transmitted every predetermined data update cycle. Figure 2 shows the time sequence diagram when commands for opening or closing a target valve are transmitted to the FN910.

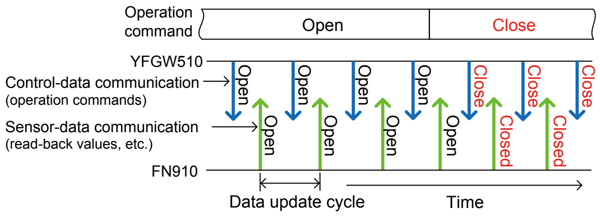

Figure 2 Transmission and confirmation of operation commands via field wireless

Time Slot and Channel Hopping

The 2.4 GHz band, which field wireless systems use, is divided into 16 channels and data are transmitted by switching these channels at every time slot of 10 ms. This channel switching operation, called channel hopping, improves the tolerance to radio wave interference in a specific channel. During a time slot of 10 ms, between two field wireless devices, one device sends a communication packet containing control data or sensor data and the counterpart replies its acknowledgement (Ack). Figure 3 shows communication using time slots and channel hopping.

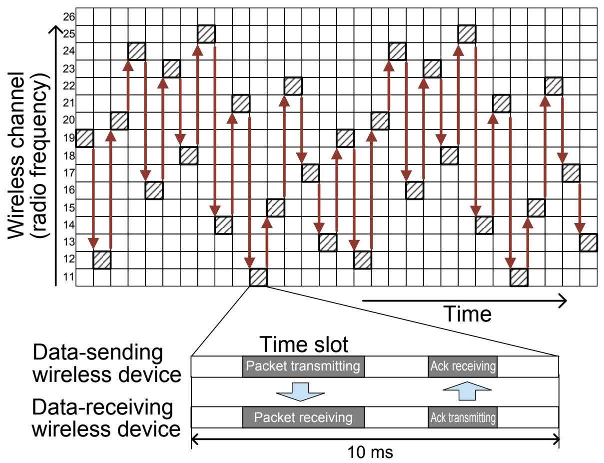

Figure 3 Communication using time slots and channel hopping

Time Slot Schedule

In the field wireless system, the timings when each field wireless device can transmit data are allocated to specific time slots in advance. This allocation, called the time slot schedule, is determined in the YFGW410 and downloaded to each field wireless device. Each field wireless device transmits or receives data at its assigned time slots. The maximum number of field wireless devices connectable to a single YFGW510 depends on the time slot schedule.

TECHNOLOGIES FOR ENHANCING COMMUNICATION RELIABILITY

This section describes technologies for enhancing the reliability of the control-data and sensor-data communication.

Figure 4 shows communication routes from YFGW410 to FN910 via two hops where YFGW510s are redundant and two repeaters are used for redundancy. The routes marked [1] to [4] are for control-data communication, and the routes marked (1) to (6) are for sensor-data communication. Time slots are allocated for each route.

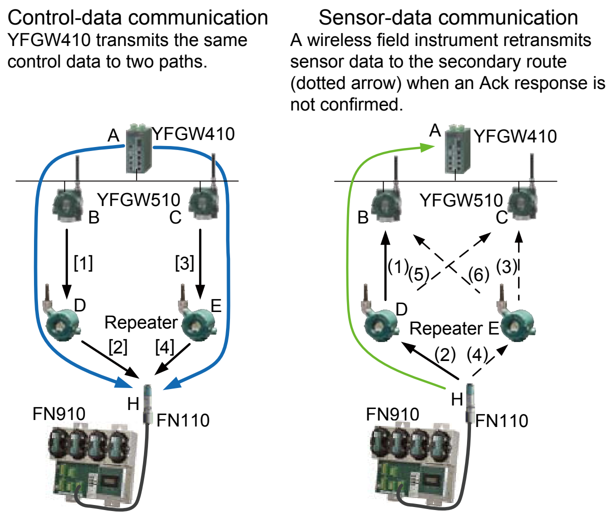

Figure 4 Redundant communication paths in a field wireless system

Redundant Communication Paths for Control-data Communication

In control-data communication through redundant paths, the YFGW410 or YFGW510 transmits communication packets containing the same control data to both routes. With this feature, for example, even when a failure occurs in the route [1], [2], communication packets reach the FN910 via the route [3], [4].

In the conventional redundancy method, a communication packet is transmitted to one path, and when a communication failure occurs, the packet is retransmitted to the other path. To switch communication paths, it is necessary to create a new time slot schedule including a new communication path, and download it again to target field wireless devices. This process takes about 10 minutes, during which time communication is suspended.

Meanwhile, the new method whereby the YFGW410 always transmits communication packets to both redundant routes eliminates the need to switch communication paths, and ensures the real-time operation required for control-data communication even when a communication failure occurs.

Redundant Communication Paths for Sensor-data Communication

In sensor-data communication, when an Ack response is not confirmed, communication packets are retransmitted to the sub-route shown by dotted arrows in Figure 4. For example, if a failure occurs in route (2), packets are retransmitted to route (4). When another failure occurs in route (3), packets are retransmitted to route (6).

Increasing the Maximum Number of Retries

The YFGW410 has a setting item called Retry Mode. When " × 2" is selected, the maximum number of retries is increased compared with the case of "Normal." When Retry Mode is set to " × 2" in the case of Figure 4, 8 (4 × 2) data slots and 12 (6 × 2) data slots are allocated for control-data and sensor-data communication respectively, increasing the number of time slots for retries. This improves the tolerance to communication failures.

Detection of Control-data Communication Anomaly

There is a case when sensor-data communication remains normal but control-data communication fails depending on where communication failures occur. The left side of Figure 5 shows such a case where control-data communication is interrupted due to communication failures at two locations caused by radiowave-blocking moving obstacles or the like. When the FN910 cannot receive control-data communication packets for a specific number of times, its self-diagnostic function changes its status to abnormal, and the status is embedded in sensor-data communication packets and transmitted to the YFGW410. Thus, as shown in the right side of Figure 5, the host system can detect the anomaly.

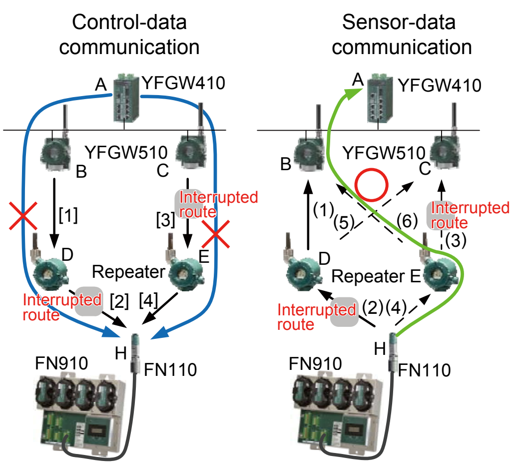

Figure 5 Informing anomaly through control-data communication

WIRELESS OPERATION COMMAND RELIABILITY

The following is the calculation of the probability that wireless operation commands for opening or closing valves reach the FN910 (hereafter called "probability operation command arrival rate") in the case of the configuration shown in Figure 4. Because the shortest data update cycle provided by the FN910 is 4 seconds, a shutoff valve closing operation can be started within 10 seconds at the longest if the operation command from the host system reaches the FN910 within two data update cycles.

Assuming that all packet error rates (PER) [3), (4] between each field wireless device are the same in the routes for control-data communication, operation command arrival rates R are calculated. Figure 4 shows a case of redundant routes via two hops.

PERs of the route [1] from B to D and the route [2] from D to H are defined as PER_1 and PER_2 respectively. The operation command arrival rate R_{BH} from B to H is calculated by the following equation.

$$R_{BH} = (1-PER_1)\,(1-PER_2)$$

This is an operation command arrival rate when the route is not redundant.

Similarly, the operation command arrival rate R_{CH} from C to H is shown below.

$$R_{CH} = (1-PER_3)\,(1-PER_4)$$

By using these, the operation command arrival rate R_{AH} for redundant routes from A to H shown in Figure 4 is calculated as follows.

$$R_{AH} = 1- (1-R_{BH})\,(1-R_{CH})$$

R_{AH} in the case where one-time retry is added is shown below.

$$R_{AH} = 1 - (1-R_{BH})\,(1-R_{CH})\,(1-R_{BH})\,(1-R_{CH})$$

Table 1 shows calculation results of the operation command arrival rate R_{AH} in the configuration of Figure 4, when PER is 5%, 10%, and 15%.

Table 1 Operation command arrival rate

PER	Operation command arrival rate*	
	First time data update	With one-time retry
5%	99.9909631%	99.9999992%
10%	99.8696790%	99.9998302%
15%	99.4070037%	99.9964836%

* Two-hops communication through redundant routes with one-time retry

FN910 FIELD WIRELESS SOLENOID-VALVE CONTROL MODULE

Overview

The FN910, in accordance with operation commands sent from the host system, drives a solenoid valve by using built-in batteries, and operates a pneumatic valve actuator remotely. The FN910 conforms to intrinsic-safety standards. Combined with the FN110, a solenoid valve and limit switches, it can be installed in hazardous areas such as tank yards, and used for remote control of a shutoff valve.

Device Configuration for Operating Pneumatic Valve Actuator

The left side of Figure 6 shows the external view of the FN910, and the right side shows the device configuration for operating a pneumatic valve actuator. The FN110, a solenoid valve, and limit switches, which detect the open/closed state of the shutoff valve, are connected to the FN910, and they cooperatively operate a pneumatic valve actuator. For the solenoid valve, a latching type whose direction is switched by applying a pulse voltage, consuming less power, is used. Thus, the built-in batteries of the FN910 last for ten years under the conditions where the valve is driven once an hour and the data update cycle is 4 seconds.

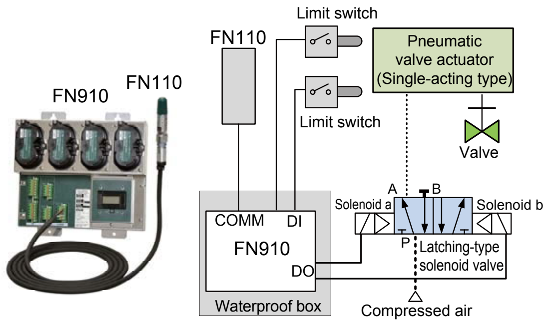

Figure 6 External view of the FN910 and device configuration for operating a pneumatic valve actuator

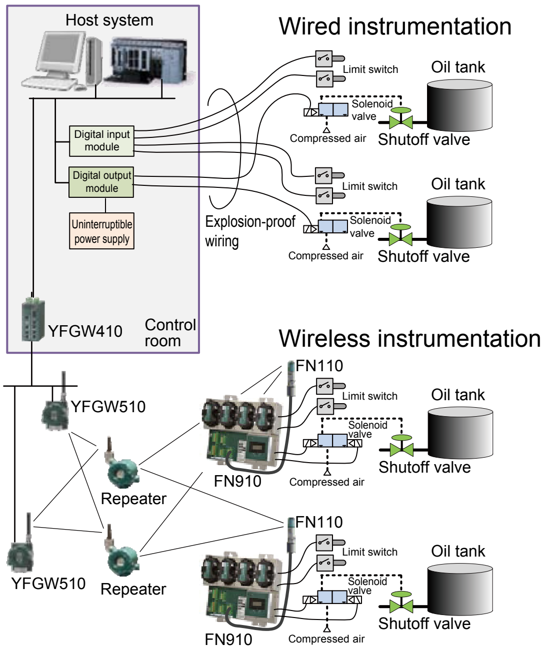

Figure 7 Wired and wireless instrumentation for operating shutoff valves

Mechanism of Operating the FN910

The FN910 applies a pulse voltage to the latching type solenoid valve when the operation command, received through control-data communication during every data update cycle, changes. This switches the path of compressed air, toggling application and release of the compressed air to the pneumatic valve actuator, thus closing or opening the target valve. The states of the limit switches are sent to the host system along with the read-back value of the operation command through sensor-data communication.

Comparison with Wired Instrumentation

Figure 7 shows examples of wired and wireless instrumentation for operating shutoff valves for oil tanks. The wired instrumentation requires wiring work from hazardous areas to the control room while conforming to explosion-proof requirements, and also requires uninterruptible power supplies to back up the power to the solenoid valves in case of power failure. On the other hand, the wireless instrumentation using the FN910 requires no wiring work, and is less susceptible to power failure because the built-in batteries of the FN910 drive the solenoid valves.

CONCLUSION

In the new method, communication packets for control-data communication are transmitted to both redundant routes. Wireless field instruments have two chances for receiving the same control data through two routes within a single data update cycle. This method achieves transmission of control data with higher reliability and shorter time lags compared with the conventional method in which a transmission path is switched upon communication failure and a communication packet is retransmitted. In addition, the FN910 achieves wireless operation of a pneumatic valve actuator while driving a solenoid valve with its built-in batteries. Thus, the wireless system using the FN910 not only requires lower wiring cost but also is less susceptible to wire disconnection and power failure caused by accidents or disasters, compared with conventional wired systems in which solenoid valves are remotely driven through wires.

By using the highly reliable field wireless control-data communication, Yokogawa aims to increase the use of wireless instrumentation which features flexible installation and elimination of wiring work.

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