Verification of Characteristics of Wireless Instruments installed in Plant Facilities
～Evaluation of Stability and Reliability of Wireless Communication in Plant Field～

Kazushige MINAMIZATO, Hidehiko FURUYA, Norihiro TANAKA and Toru YAMAGUCHI

NIPPON STEEL & SUMIKIN ENGINEERING CO.,LTD.,JAPAN

Abstract: It is well known that process variables such as flow, pressure and temperature in plant field networks are normally transmitted by cables between instruments and central control systems. Recently, wireless instrumentation technology has attracted wide attention in the process automation field, intended to achieve 3 main benefits: (1) reduced costs by minimizing cable installation run lengths, (2) as a backup strategy for Business Continuity Plan (BCP) in case of incident, and (3) advancement of measurement technology. However actual application of wireless technology to plant facilities has historically included some uncertainty due to unknown performance characteristics at operating plant sites. The key performance characteristics of interest include "stability" and "reliability" of wireless instrument communication at operating plant locations; subjected to environmental conditions including metal obstructions like tanks, boilers, pipes and, production equipment. Due to the uncertainty, the adoption of wireless technology at operating plant sites has been slow despite the availability of commercial industrial wireless sensor products since 2007. In this paper, verification results of characteristics of wireless instruments obtained by field tests conducted in actual plant facilities are reported, as well as, our future plans to optimally apply this technology to plant facilities.

1. INTRODUCTION

The on-site process control systems are critical for safe and secure operation of plant operations. These systems collect and transmit process measurements to central control systems to provide an accurate status of the plant's operations. Using the field measurements, the central control system sends output instructions to control devices in the field to manage the production processes.

It is well known that process variables such as pressure and temperature measured in a field are distributed to a central control system by the wired cables from every IO-point. This is also known as 'Cable Broadcasting'.

During the past few years, implementations of 'wireless instrumentation' to support applications at plant sites have been expanding in mainly outside of Japan. These systems use industrial radios to transmit process data to the plant's central control system.

Most mainstream instrumentation networks use the 'Cable broadcasting' technology which transmits process variables to the central control system using wired cables from every I/O point. This is an expensive approach due to the resource of intensive installation and maintenance requirements of physical cables.

The fieldbus wiring approach which uses a 'shared fieldbus backbone' is an improvement on the 'Cable broadcasting' model because it reduces cabling requirements in plants and enables flexible cabling architectures. "The wireless instrumentation" technology is a further improvement over the fieldbus model by expanding the flexibility of network architecture and the choices for field device locations.

Figure 1 shows the expected benefits of using wireless instrumentation technology.

Superior Attributes of Wireless Networks	Expected Benefits
1) Reduced communication cable runs for field device network 2) Higher flexible and extensible network 3) Lower complexity for engineering and site planning 4) Reduced power cable runs and reduced external power supply requirements	• Reduced construction costs and timeframe • Reduced facility design constraints and facility design costs and timeframe. • A backup (BCP) / continuity of operations and disaster prevention solution. • Quality improvement for instrumentation. (For example locating sensors in a rotating drum) • Higher intensity of site monitoring; easy to add new devices and to expand devices into locations not easily reached by wires. • Reduced wiring maintenance costs

Figure 1 Expected Benefits by applying Wireless Instruments

However, there are several issues required to be resolved which should fully realize the value of wireless instrumentation, most importantly in the area of international standardization for industrial wireless technologies.

Figure 2 lists the key issues that requiring resolution to ensure that industrial wireless technology would gain broad adoption; and lists the resolutions that have been implemented in standards-based industrial wireless technology.

Issue# 4 *'Stability and Reliability'* and issue# 5 *'Electronic Wave Interference'* are the two greatest barriers for adoption of industrial wireless technology for automation in process industries.

Process automation production facilities are constructed using a large amount of metal equipment such as tanks, boilers, pipes, and mounting apparatus. As a result, the facility itself is the main obstacle for wireless communication technology because metal materials readily reflect radio waves. Consequently, automation engineers are skeptical about the "stability" and "reliability" of industrial wireless networks for transmitting process data. The fact that wireless signals are invisible, only adds to the automation engineer’s skepticism.

Also, because industrial wireless networks share the 2.4GHz radio frequency band with WiFi (IEEE 802.11.xx) transceivers, automation engineers question how multiple wireless networks can coexist in the same 2.4 GHz spectrum without performance degradation.

The user’s concerns cannot be assuaged by persuasive technical explanations offered from wireless instrumentation device vendors. The user demands field trials that include a performance verification tests in the actual plant based upon typical wireless application use-cases designed by the user.

This paper describes results from verification testing of "stability and reliability of the wireless communication” for wireless instruments installed at actual plant facilities of our company. The paper also describes our future plans for the next phase for optimally applying this technology to plant facilities.

Wireless Technology Issues	Solution / Response
#1 Wireless radios behave differently in different countries/regions	Use a license-free and application-free radio spectrum throughout the world
#2 Smaller battery size and longer battery life	Design field devices for low power consumption
#3 Security concerns about unauthorized listening to over the air communication and about malicious tampering with the signals	Implement data encryption schemes, device authorization in networks and, certification of devices
#4 Stability and reliability of communication	Include communication re-try functions and provide flexibility for network configurations
#5 Co-existence with / interference from other wireless radio applications sharing the 2.4GHz spectrum	Implement channel-hopping scheme and channel black/white listing capabilities

Figure 2 Main Issues and Solutions for Wireless Instruments

2. VERIFICATION BY FIELD TRIAL

2.1 Performance index

In this evaluation, we used the following indexes to evaluate stability and reliability of wireless communication:

(1) RSSI (Received Signal Strength Indication)
(2) PER (Packet Error Rate)
(3) Data Loss Rate

2.1.1 RSSI

RSSI (Received Signal Strength Indicator) is an indicator of the power level being received by the antenna in wireless transceiver (Unit: dBm).

If there are obstructions along the wireless communication path, Radio wave intensity fluctuates by diffraction or reflection and so on. Therefore, RSSI measurement is useful to evaluate the stability and reliability of wireless communication.

2.1.2 PER

PER (Packet Error Rate) is the number of incorrectly received data packets divided by the total number of transmitted data packets.

Table1 is an example to illustrate how we structured PER calculations. Using the Table1 example, the PER is calculated to be 20% (number of error packets: 5, divided by the total number of transmitted packets: 25).

Please note that PER is not equal to “wireless communication error rate”. To calculate “wireless communication error rate”, the number of retry communications should also be included in the calculation. Using the Table 1 example, wireless communication opportunity per data update is up to 5 times including 4 retries. So that, in this case, “wireless communication error” would be 0.032% (=20%^5)

Table 1 Example of PER calculation
(Data publishing period: 10sec, Retry: up to 4 times)

		Communication time				
		1st	2nd	3rd	4th	5th
1	0:00:10	G				
2	0:00:20	G				
3	0:00:30	NG	G			
4	0:00:40	G				
5	0:00:50	G				
6	0:01:00	G				
7	0:01:10	G				
8	0:01:20	G				
9	0:01:30	G				
10	0:01:40	NG	G			
11	0:01:50	G				
12	0:02:00	G				
13	0:02:10	NG	NG	G		
14	0:02:20	G				
15	0:02:30	G				
16	0:02:40	G				
17	0:02:50	NG	G			
18	0:03:00	G				
19	0:03:10	G				
20	0:03:20	G				

2.1.3 Data Loss Rate

RSSI and PER are the generally accepted wireless industry measures for evaluating the quality of wireless communication. However, regardless of accepted industry metrics, users are more interested in whether measured process data actually reached its intended destination, the central control system. If the process control data does not arrive at the central control system in a timely manner, then the quality of wireless communication is not useful. Therefore, we also measured the “Data Loss Rate” at the central control system.

2.2 Evaluation items and results of the field test

2.2.1 Verification of multi-vendor interoperability

This paper reports on results of field tests using certified ISA100.11a compliant (certified ISA100 Wireless™) wireless instrumentation devices in the actual plant. ISA100.11a is international standard IEC 62734 and using certified ISA100 Wireless™ devices allows us to test interoperability between wireless devices supplied by different vendors. The use of a multi-vendor device configuration allowed us to observe any impact that a multi-vendor ISA100 Wireless™ configuration may have on the performance and functionality of wireless communication. The field test was designed with one wireless network that implemented four certified ISA100 Wireless™ field devices from 3 vendors; Vendor-A provided a Multi-point Temperature Transmitter and Pressure Transmitter, Vendor-B provided a Gas Detector and, Vendor-C provided a Pressure Transmitter. Figure 3 shows the system configuration used during the field tests. The 4 wireless field devices were installed in the actual plant, configured to communicate with a wireless access point. All of the communication data generated during the testing was saved to a Personal Computer (PC) attached to the gateway on the ISA100.11a network. The RSSIs and PERs were captured in a Field Wireless Monitor software tool running on the PC.

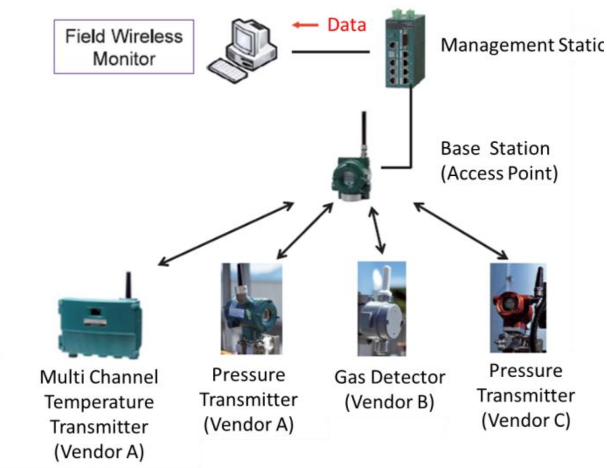

Figure 3 Configuration Diagram for verifying the Characteristics of Multi-Vendors

Several wireless device and network configurations were used during the field trials. Figure 4 shows one of the network configurations in which at least one device does not have a line-of-sight signal path. The location of the wireless instrumentation is such that it cannot be seen at all from the base station. As shown in the photograph, the metal tank is installed immediately behind the base station. Under this network and device configuration, the field test was carried out using 10 second data update intervals (and allowing for 5 communication retries).

The results of this test are tabulated in Figures 5-7 and show the graphs of RSSI and PER for each of the 4 wireless instrumentation devices from the 3 vendors.

It was confirmed that devices from different vendors could communicate with each other without any problems in a single ISA100.11a wireless network at same time. Furthermore, the multi-vendor configuration comprised of 3 device vendor companies, achieved nearly the same communication performance. RSSI was not less than -70dBm and the PER was 10% or less.

The field trial data show that the ISA100.11a compliant devices using wireless modules certified by WCI (Wireless Compliance Institute) have no difference in wireless communication performance.

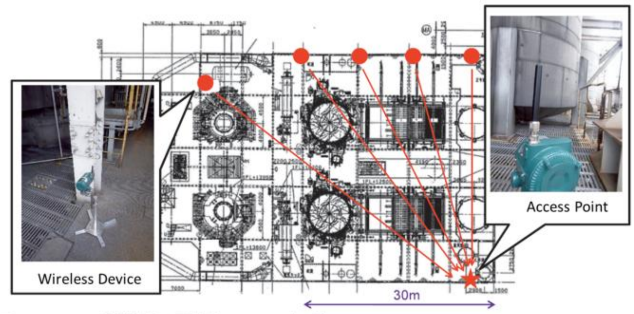

Figure 4 Installation Layout of Wireless Instruments for verifying the Characteristics of Multi-Vendors

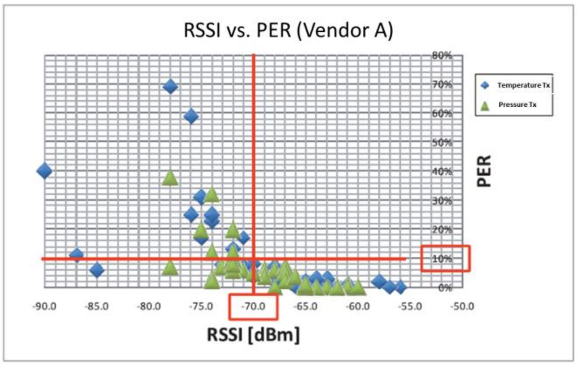

Figure 5 Relative Relationships between RSSI and PER in case of Vendor-A's products

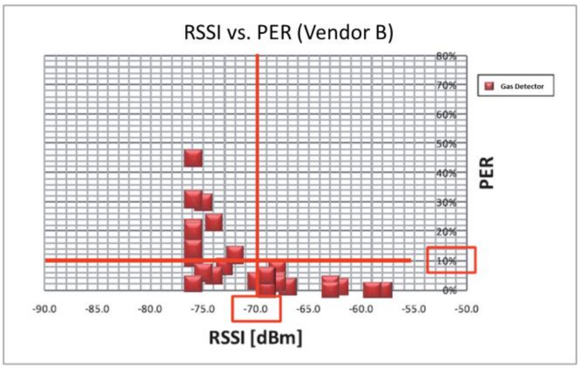

Figure 6 Relative Relationships between RSSI and PER in case of Vendor-B's products

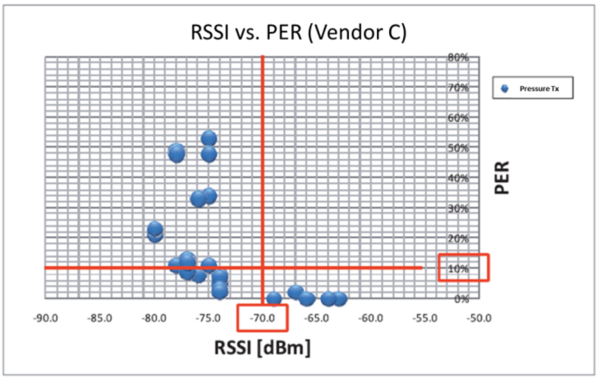

Figure 7 Relative Relationships between RSSI and PER in case of Vendor-C's products

2.2.2 Evaluation of communication stability

In the actual plant operation, the electromagnetic environments affecting the wireless communication varied significantly during the course of the field trials. As a several examples, differences were triggered by changing weather conditions, and by the field workers moving around with transceivers for on-site patrol. We believe evaluating wireless network performance over a short one-hour period would be insufficient. Therefore, to generate realistic test results, we designed field trials to continuously observe communication stability over a one-week timeframe under normal plant operating conditions.

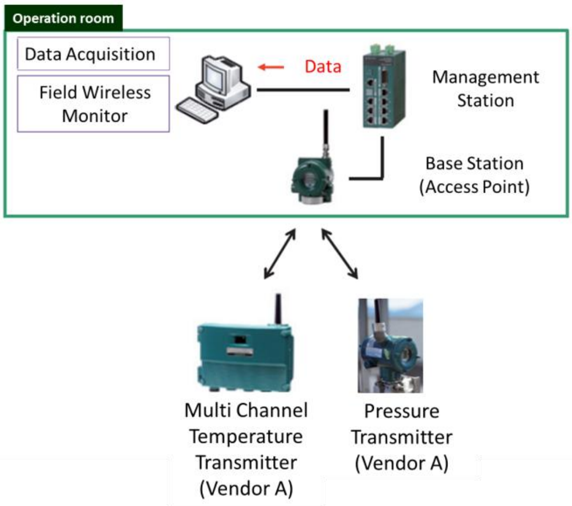

Figure 8 System Configuration Diagram for evaluating the Wireless Communication Stability for 1 week

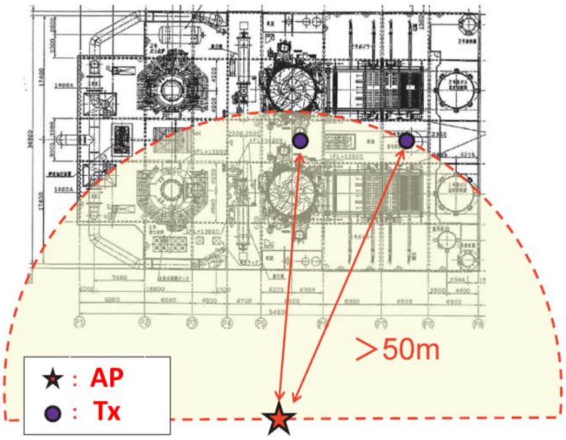

Figure 9 Installation Layout of Wireless Instruments for evaluating the Wireless Communication Stability for a week

Figure 8 shows the system configuration used during the 1 week evaluation and Figure 9 shows an example of device arrangement in the site. Pressure Transmitter and Temperature Transmitter of vendor-A were placed in the center of the plant facility and the wireless Access Point (AP) and Personal Computer (PC) were located in the operation room about 50 meters distance from the transmitters. The RSSI and PER were measured using the Field Wireless Monitor tool running on the PC. The data loss rate was captured by the data collection tool along with the RSSI and PER.

The test results for 1 week trial are shown in Figure 10. This figure is graphed the PER at once every hour during the test period of 1 week. The results show that the PER ranges from a low of 3% up to a high of about 19%. **However, the data loss rate during this period was measured as "zero"; meaning that within a radius of 50m, it was confirmed that the continuous process data was transmitted wirelessly to the control system without any losses.**

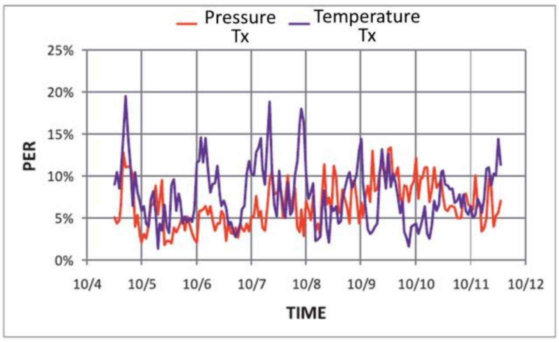

Figure 10 Results for evaluating the Wireless Communication Stability for 1 week in case of Vendor-A's products

3. EXPECTIONS OF WIRELESS INSTRUMENTAION

3.1 Low Cost

- It is possible to apply wireless technology to instrumentation, particularly when implemented using appropriate engineering.
- It is a problem that wireless products have higher unit prices than a wired products.
- However, we expect that the price of wireless products will go down over time and as more vendors introduce competing wireless products.

3.2 The expansion of the measurement targets

- End users would like to see the portfolio of commercially available wireless products expand significantly to cover more applications.

3.3 Easier data collection

- The radio instrumentation is attractive as means to collect the data in the plant easily (i.e. not necessary to confirm the existing cabling system).
- Therefore we strongly expect early realization of above-mentioned 3.1 and 3.2

4. CONCLUSIONS

The following test results were confirmed.

- ISA100.11a standard compliant wireless devices demonstrated interoperability in the same network. And communication performance of the multiple vendor devices are nearly the same.
- The communication distance under non-line of sight condition with metal obstacles was about 50 m without any data losses (under the condition of data publishing period of 10 seconds).

Based on the test results, we conclude that ISA100.11a wireless technology offers sufficient performance to provide a stable and reliable network for deploying into actual field sites. We recommend that implementers follow the steps below during the planning phase and before commissioning of the wireless network.

1) Perform the site engineering to ensure a good network design, considering communication distances, extent of obstructions, multipath environments.
2) Conduct the network engineering such as layout planning, data publishing period, number of retries
3) Validate the network planning by measuring RSSIs and PERs at the pre-commissioning stage after deploying the devices

The redundant function such as Duocast which is defined by the ISA100.11a standard (redundant communication path with two access points) has not been evaluated during this field trial. However, wireless instrumentation technologies are being enhanced for higher stability and reliability to adequately support control applications.