An all-in-one HART modem with diagnostic, power-supply, and multiprotocol connective functions

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Key words

Process automation, DX, HART, communication problems, HART communication check, communication noise, looped power supply, analysis, device management, valve diagnosis, SFN, DE

The digital transformation (DX) of process automation plants using Highway Addressable Remote Transducer (HART) communication is underway. In this process, communication problems are sometimes encountered, requiring analysis and response using a variety of equipment. We have now developed the HART/SFN/DE-compatible model AZ-1SHM smart HART modem, which can check the operation of HART-enabled devices in the field and analyze HART communication problems without using various external analytical equipment.

1. Introduction

The digital transformation (DX) of process automation (PA) plants using Highway Addressable Remote Transducer (HART) communication is underway. Digital transformation using HART communication can be carried out in phases using existing 4–20 mA analog instrumentation assets, including control software for the distributed control system (DCS), to minimize impact on production. When an analog field device is replaced by a HART-enabled field device (hereafter simply "HART field device") and the I/O module of the DCS is changed to a HART-compatible module or a HART-compatible device management host system is introduced by adding a HART communication unit, HART communication enables access to many of the parameters of field devices' functions. This access can be expected to result in reduced loop check time and the ability to use the field devices' self-diagnosis information for maintenance.

Communication problems may be encountered, however, such as noise affecting the HART signals or failure to obtain the required wave amplitude defined in the HART communication specification due to a lack of load resistance, necessitating analysis in the field. Analysis could require various systems and devices, such as a multimeter, oscilloscope, bus analyzer, HART-compatible field communicator, voltage/current generator, or other HART field devices, which may be cumbersome to continually carry around the site.

Recently, we have developed a smart modem (model AZ-1SHM, abbreviated 1SHM), a multi-protocol modem supporting HART communication, Azbil's smart field network (SFN), and digital enhancement (DE) field device communication protocols. The 1SHM enables operation checks when introducing HART for the first time, as well as problem analysis for HART communication, without the need to use various systems or devices.

2. Structure of the 1SHM

The 1SHM consists of the unit shown in figure 1 and the Support Tool, which is software.

2.1 1SHM hardware

The 1SHM unit is small enough to be held in one hand and operated with a thumb. On the back there is an indentation for the index finger to make the unit easy to hold during operation. The buttons on the operating panel are arranged from the top in order of use and are centered to allow operation by either the right or left hand.

Fig. 1. 1SHM

Because this is a compact unit designed to be used with one hand, the part count has been reduced as much as possible and parts that do not produce much heat were selected to avoid an increase in temperature.

The unit also has a strap hole so that it can be hung during use in the field, and a dedicated silicone jacket is available to increase resistance to impact.

Fig. 2. 1SHM with silicone jacket

The unit connects to a field device with the field device cable shown at the upper right of figure 1. The test clips at the end of the field device cable shown in figure 1 can be replaced with alligator clips that are provided with the unit.

The unit connects to a Windows PC or tablet running the HART host application (hereafter "the HART host") or the Support Tool using a USB Type-C® cable. In a country or region where authorization to use radio waves has been obtained, the Support Tool can be used to configure the unit to connect wirelessly to the PC or tablet running HART host via Bluetooth® Classic v4.2, or to the PC or tablet running the Support Tool via Wi-Fi on a network using IEEE 802.11 b/g/n.

The unit operates on power from the PC or tablet via the USB cable, or on its internal batteries.

As a result of miniaturization and reduction of the number of components, the weight of the unit has been reduced by 80 % compared to the previous system where various analytical devices were used, reducing CO_2 emissions, and contributing to the reuse and recycling of resources, environmental conservation, and resource conservation.

2.2 Support Tool

The Support Tool is software that runs on a PC or tablet when it is connected to the hardware unit. It serves as the user interface for license authentication, which is mandatory before using the 1SHM, and for HART communication analysis. The functions of the Support Tool are described in sections 3.2 and 4. Figure 3 shows an example of the Support Tool screen. The required screen size is at least 400 × 700 pixels. The screen is designed so that the same image can be viewed on either a PC or tablet. When using a monitor with high screen resolution, a wide display can be viewed by pressing the maximize button, etc.

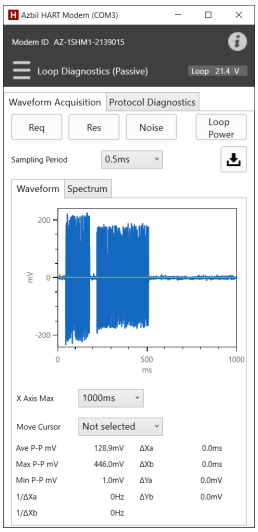

Fig. 3. Example of Support Tool screen

3. Functions of the 1SHM

3.1 Modem

The 1SHM is a modem for communication between field devices and the HART host or Azbil's model CFS100 field communication software, both of which set up and adjust field devices. Multiple protocols—HART, SFN, and DE—can be used without the need to switch between them.

3.1.1 Modem for the HART host

When the 1SHM is connected to a HART host running on the PC via a USB cable, and when the COM port corresponding to the USB driver (Azbil HART and SFN DE Serial Port) included in the product package is selected as the destination on the HART host, the 1SHM functions as a HART modem.

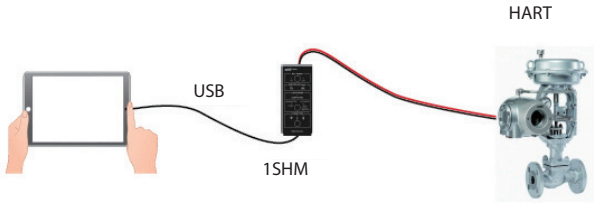

Fig. 4. HART host USB connection

In a Bluetooth connection, for the HART host running on Windows, the COM port on the outgoing side should be selected as the destination after pairing the devices. For a HART host running on Android, the 1SHM should be selected as the destination after pairing.

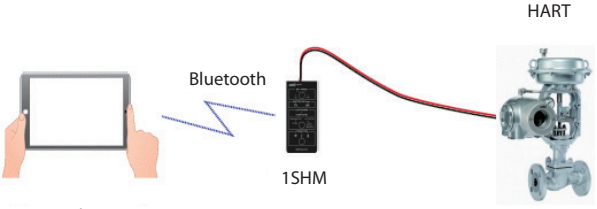

Fig. 5. HART host Bluetooth connection

3.1.2 Modem for the CFS100

The 1SHM functions as a USB modem for the CFS100. On the CFS100 startup screen, selecting HART or SFN/DE starts a connection with the field device. The 1SHM automatically detects the communication protocol from the CFS100 and operates as a modem compatible with HART, SFN, or DE.

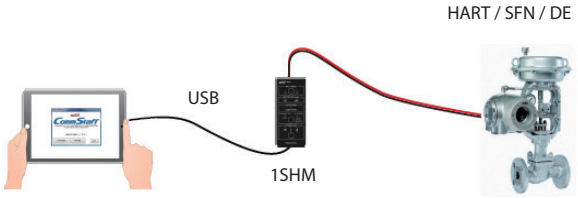

Fig. 6. CFS100 connection

3.2 Analysis of HART communication

The 1SHM alone or with the Support Tool can be used as a field service tool to analyze HART communication problems in the field. Monitoring mode and HART master mode are available for communication analysis with the Support Tool.

Details of onsite communication analysis work using the 1SHM are given in section 4.

3.2.1 Monitoring mode

In monitoring mode, the Support Tool monitors HART communication between the HART host and the field device, and also noise, without the need to transmit a HART command from the 1SHM.

Figure 7 shows an example of a USB connection. Wi-Fi connection is also possible.

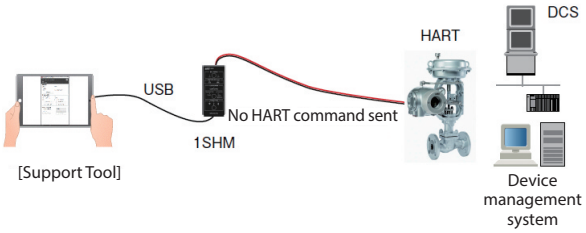

Fig. 7. Monitoring mode (example with USB connection)

3.2.2 HART master mode

In HART master mode the Support Tool, which serves as the HART host, sends HART commands to the connected field device and monitors it. In this case, whether to communicate as a primary master or a secondary master can be selected. If there is no response from a connected field device, it is also possible to intensify the signal and resend the command.

The 1SHM has a safety function that restricts switching to master mode if HART communication is detected in the destination loop. This prevents HART signals sent from the Support Tool from accidentally affecting HART communication in the destination loop, and it keeps the HART host from detecting errors such as a communication timeout.

Figure 8 shows an example of a USB connection. Wi-Fi connection is also possible.

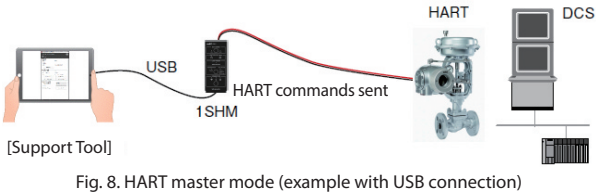

Fig. 8. HART master mode (example with USB connection)

3.3 Powering of the field device

3.3.1 Voltage/current generation function

While operating as a modem or a HART communication analysis device, the 1SHM alone can supply power to a field device (loop power supply).

Using the buttons on the unit or configuring settings in the Support Tool, 24 V DC can be supplied to a transmitter or a DC current can be supplied to an actuator. Current can be supplied in the range from 2.4 mA (–10 %) to 23.2 mA (120 %). However the upper limit depends on the impedance of the field device to which the current is supplied.

3.3.2 Communication load resistance

In the loop power supply circuit of the 1SHM, a load resistance of 250 Ω, which is required for communication, is connected with the power supply in series. When using HART, SFN, or DE communication while supplying power to a field device, there is no need to supply an external load resistor, although there are some exceptions such as four-wire field devices.

3.3.3 Safety functions

Because the 1SHM can be used in operating plants, it has a safety function to reduce the risk of accidentally causing a positioner to change its degree of opening by utilizing power from the 1SHM's loop power supply.

If the 1SHM detects external power supplied to the connected field device, it will not start the loop power supply. In addition, if the 1SHM detects that the connected field device is no longer connected at the start of or during loop power supply, it stops the supply of power. By operating in this way, the 1SHM prevents its terminals when they are supplying power from coming into contact with an operating field device and prevents unintentional startup of the loop power supply.

4. Onsite analysis work using the 1SHM

This section gives examples of cases where onsite work that formerly would be done using various systems and devices can be done easily in a short time with the 1SHM.

4.1 Checking the status of power supply to the connected loop

4.1.1 Display on the unit

When the 1SHM detects that power is being supplied between the terminals of the cables on the field device side (destination loop), the LOOP ACTIVE display (LED) on its operating panel turns on (fig. 9).

If this LED is on, and the 1SHM is not supplying power to the field device, the 1SHM determines that power is already being supplied and will not supply power.

Fig. 9. LOOP ACTIVE display on the 1SHM operating panel

4.1.2 Loop voltage display by the Support Tool

As shown in figure 10, the amount of loop voltage can be checked on the Support Tool screen. In both monitoring and HART master modes, when the waveform display and communication content are refreshed, the loop voltage figure is also updated.

Fig. 10. Support Tool loop voltage display

4.2 Checking the communication waveform and noise

With the 1SHM, the communication waveform and noise, which are usually checked using an oscilloscope, can be displayed and checked using the Support Tool. The 1SHM takes 4096 samples to acquire a single waveform. The sampling cycle is specified from the options listed in table 1 using the Support Tool.

Table 1. Sampling cycle & sampling time

Sampling cycle	Sampling time	Max. horizontal axis time
0.02 ms	81.92 ms	10 ms
0.1 ms	409.6 ms	100 ms
0.5 ms	2048 ms	1000 ms
1 ms	4096 ms	4000 ms

The result of sampling is displayed on a chart, with the vertical axis and the horizontal axis indicating voltage (mV) and time respectively. For visibility on a small screen, the scale on the vertical axis is automatically adjusted, and the horizontal axis initially shows the maximum horizontal axis value (shown in table 1) for the specified sampling cycle. The user can freely change the scale on the horizontal axis when the chart is displayed.

Figure 11 shows a sample HART communication waveform (left) and a sample noise waveform (right) at a sampling cycle of 0.5 ms. As seen in the figure on the left, HART communication appears as a repeating waveform in two blocks, one for the command and the other for the response. In an environment where the noise level is high, these blocks may be buried under the noise waveform so that it is not possible to clearly distinguish them.

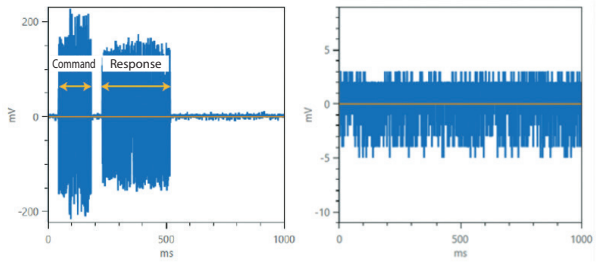

Fig. 11. A HART communication waveform (left) and noise waveform (right)

4.2.1 Monitoring mode

In monitoring mode, the type of chart displayed by the Support Tool after sampling can be selected from the following options:

1. Display starting with a HART command
2. Display starting with a HART response
3. Display starting at the time when the button is pressed

In 1 and 2 above, the HART signal waveform is shown at the beginning of the chart, and a time error occurs if the HART signal cannot be detected. With these options, the presence of the HART signal and waveform can be checked efficiently. Option 3 can be used to check the noise level on the communication path.

4.2.2 HART master mode

In HART master mode, the 1SHM issues HART command 0 (Read Unique Identifier [3]), and a waveform starting from the command is shown on the chart. In this mode, a chart can also be displayed using the time when the option 3 button in section 4.2.1 is pressed as the starting point.

4.3 Spectral analysis

In either monitoring mode or HART master mode, the spectral intensity for each frequency of the sampled signals can be shown on a chart to check the noise level near HART signal frequencies. Figure 12 shows an example of spectral analysis during HART communication. If the noise level near HART signal frequencies with high values (1200 Hz: 1, 2200 Hz: 0) is high, the impact on communication is a concern.

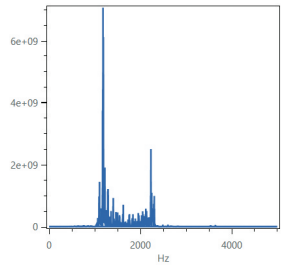

Fig. 12. Result of a spectral analysis during HART communication

4.4 Monitoring communication content

The details of HART commands, responses, and burst communication detected by the 1SHM are decoded and dynamically displayed along with aggregation results by the Support Tool.

Figure 13 shows an example of how communication content is displayed. The communication content can be viewed as an enlarged image or by scrolling. In addition, figure 14 shows an example of communication aggregation results.

```
0000 FF05 STX S- 0x82 0x36051FE297 - 003 000 - -
0187 FF05 ACK S- 0x86 0x36051FE297 - 003 016 0x00
0428 FF05 STX S- 0x82 0x36051FE297 - 003 000 - -
0039 FF06 ACK S- 0x86 0x36051FE297 - 003 016 0x00
0553 FF05 STX S- 0x82 0x36051FE297 - 003 000 - -
0105 FF05 ACK S- 0x86 0x36051FE297 - 003 016 0x00
```

Fig. 13. A communication content display

Communication Stats

Master Mode	Send	Receive	Error
Primary	0	0	0
Secondary	6	6	0
Burst	---	0	---
Frame / Parity	---	---	0

Fig. 14. Sample communication aggregation results

By monitoring the communication content, one can check the content of HART communication, whether the commands and responses in primary and secondary communication are exchanged with good timing, whether or not there is a response to these communications, and so on. It is also possible to check how often burst communication occurs, as well as frame error and parity error counts.

Table 2 shows an example of the information displayed for a command, and table 3 shows the information for a response. Table 2 corresponds to line 3 in figure 13, and table 3 corresponds to line 4. For an explanation of the terms used in the tables, see references [1] and [2].

Table 2. Contents of a command display (line 3 in fig. 13)

Value	Description
0428	Interval since previous communication: 428 ms
FF05	Preamble (0xFF) count: 5
STX	Command (master to field device)
S-	Secondary (S), non-burst (-)
0x82	Delimiter field value
0x36051FE297	Long frame address value
–	Expansion bytes: none
003	HART command 3 (decimal notation)
000	Data byte length: 0 (decimal notation)
–	Response code: not applicable
–	Status byte: not applicable

Table 3. Contents of a response display (line 4 in fig. 13)

Value	Description
0039	Interval since previous communication: 39 ms
FF06	Preamble (0xFF) count: 6
ACK	Response (field device to master)
S-	Secondary (S), non-burst (-)
0x86	Delimiter field value
0x36051FE297	Long frame address value
–	Expansion bytes: none
003	HART command 3 (decimal notation)
016	Data byte length: 15 (decimal notation) One byte for command status is added to the value.
0x00	Communication status value
(Not shown)	Device Status value
(Not shown)	Description of response data bytes in HART command 3 (hexadecimal notation)
(Not shown)	Check byte value for HART PDU

4.4.1 Monitoring mode

In monitoring mode, the content of HART communication at the destination is displayed. The 1SHM does not issue HART signals. If a HART signal cannot be detected at the destination, the decoding result shown in figure 13 is not displayed. Monitoring can be stopped or resumed at any time.

4.4.2 HART master mode

In HART master mode, the 1SHM repeatedly issues HART command 0, and commands and responses are displayed. Issuing of HART command 0 can be stopped or resumed at any time.

4.5 Field device identification information check

This is a function in HART master mode used mainly to check the settings of devices removed from the plant.

The function searches for field devices connected with polling addresses 0 to 63 and displays the identification information for the specified device among those that are found.

In the case of a HART host that does not support HART multidrop, reading parameters from a field device in which something other than 0 is set for the polling address may not be easy. This function can also be used to check the details of such a field device's parameters.

Polling Address	0
HART Version	6
Manufacturer ID	---
Expanded Device Type	0x3614
Device Revision	0x01
Software Revision	0x07
Device ID	0x010000
Configuration Change Counter	128
Min.Number of Preambles (Response)	5
Loop Current Mode	Enabled

Tag	FV101
Long Tag	FCV101

Fig. 15. Field device identification information display

4.6 Process variable check

This function in HART master mode repeatedly sends HART command 3 (Read Dynamic Variables And Loop Current [3]) to the specified field device and displays its dynamic variables (PV, SV, TV, QV) and loop current values in a trend chart format. Up to five graphs (for PV, SV, TV, QV, and loop current value) can be shown at the same time on a chart. The scale on the vertical axis is automatically adjusted for visibility on a small screen.

Figure 16 shows an example of a chart when loop current is selected for the vertical axis.

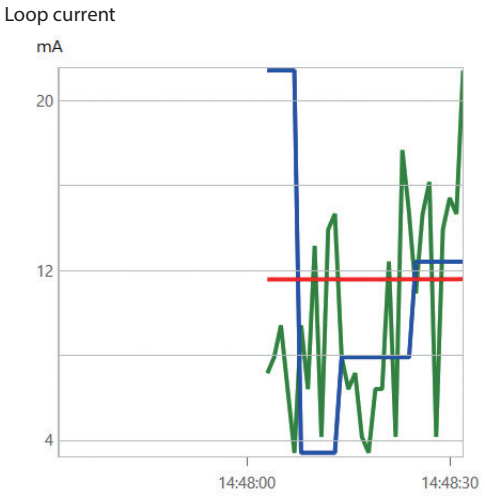

Fig. 16. Process variable check

By displaying variables such as this which are read from the field device, one can visually check whether there is a risk of interrupted communication due to the effects of noise and the like.

4.7 Pre-HART communication environment check

Before replacing an analog field device with a HART field device, it is necessary to check whether HART communication is possible without changing the existing communication path and cable. Although the easiest way to do this is to replace the analog field device with a HART field device and try communicating with the HART host, it is often difficult to prepare a HART field device.

For such cases, the 1SHM has a device mode in which it operates as a HART slave so that it can serve as a substitute for a HART field device. The 1SHM in device mode operates as a pseudo HART field device with the manufacturer ID 0x0036 (Azbil Corporation) and device type 0x3617 (SHM1). It supports all HART universal commands and common practice command 72 (Squawk [4]).

To check the communication environment, searches for the connected field device and other operations are performed on the HART host (the device management system in figure 17) after a 1SHM unit configured to operate in device mode has been wired in lieu of a HART field device. At that time, commands such as HART command 0 are sent from the HART host to the 1SHM. After receiving them successfully, the 1SHM returns a response. If the HART host confirms the expected result, it can be assumed that HART communication will be possible when a HART field device is put in place of the 1SHM.

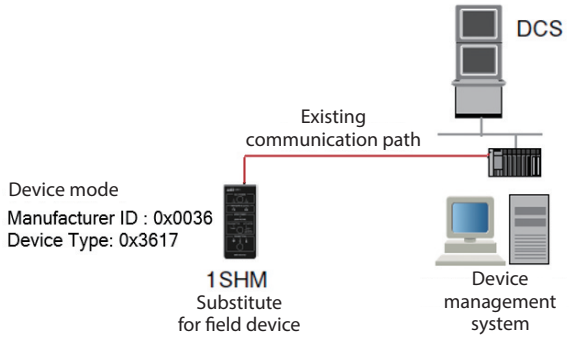

Fig. 17. Communication environment check using device mode

5. Conclusion

Based on our experience supporting onsite analysis of HART communication problems, we developed the model AZ-1SHM smart HART modem as a handheld device that is useful for operational checks after introducing the HART system and for communication problem analysis, and we provided an easy-to-use field service tool function to accompany the unit. One 1SHM unit and the Support Tool software provide the following value for onsite work:

- HART modem (wired/wireless)
- SFN/DE modem (wired)
- Current/voltage generator with a communication load resistor
- Display of the loop power supply status
- Noise and waveform display and spectral analysis
- Display of HART communication details and communication results
- Display of HART field device identification information
- Trend display of dynamic variables for HART field devices
- A substitute for a HART field device (device mode)

In addition, the 1SHM was awarded a 2020 Good Design Award and a Red Dot Award—Product Design 2021 in Germany.

It is expected that, as the digital transformation of PA plants using HART communication progresses, communication problems will be encountered and cases that require analysis will increase. Going forward, by listening to the opinions of those who need this device, we would like to enhance and improve it by (1) reinforcing the data collection and memory functions to analyze communication problems that are difficult to observe in real time, (2) enabling collaboration with cloud computing and utilizing the 1SHM for remote diagnosis, (3) improving the user interface and providing an online advice service with the Support Tool, and (4) developing an intrinsic safety version.

References

[1] FieldComm Group, *HART token-passing data link layer specification* (HCF_SPEC-081 FCG TS20081).
[2] FieldComm Group, *HART command summary specification* (HCF_SPEC-099 FCG TS20099).
[3] FieldComm Group, *HART universal command specification* (HCF_SPEC-127 FCG TS20127).
[4] FieldComm Group, *HART common practice command specification* (HCF_SPEC-151 FCG TS20151).

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