

DOCUMENTATION GUIDE



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Introduction

This document has been created to support the developing needs of *WirelessHART*® end users adopting self-organizing mesh networks within the process industry. It is intended to show how *WirelessHART* devices can be included in capital projects of any size.

This document recognizes that *WirelessHART* products are available from the HART Communication Foundation and many of its members, and thus is written in a ‘generic’ fashion which does not incorporate any ‘value added’ features available from any specific vendor.

This document assumes the reader is proficient with HART instrumentation, therefore the focus of this content will be on the unique aspects of deploying *WirelessHART* systems. Unless stated otherwise, the reader should assume the project steps are the same for HART and *WirelessHART* instrumentation.

This document is intended to serve as the basis for advanced discussions on the implementation of *WirelessHART* systems.

The *WirelessHART* System Engineering Guide is intended to show how *WirelessHART* devices can be included in capital projects of any size.

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1. SCOPE

This document includes considerations for *WirelessHART* devices through the capital project cycle as well as during the subsequent lifecycle of the *WirelessHART* device.

Differences are highlighted between HART and *WirelessHART* specifications and *WirelessHART* device types that are unique to the *WirelessHART* standard (IEC 62591).

This document does not attempt to detail minor differences between HART and *WirelessHART* devices; nor features specific to a vendor; nor provides exhaustive studies of integration with various host systems.

2. DEFINITIONS

WirelessHART is a global IEC-approved standard (62591) that specifies an interoperable self-organizing mesh technology in which field devices form wireless networks that dynamically mitigate obstacles in the process environment. This architecture creates a cost-effective automation alternative that does not require wiring and other supporting infrastructure. *WirelessHART* field networks (WFN) communicate data back to host systems with reliability demonstrated in the field in excess of 99% and are capable of both control and monitoring applications.

The similarities between *WirelessHART* and HART allow wireless devices to leverage the training of existing process organizations, minimizing change and extending the benefits of automation to end users who previously could not justify the costs associated with typical wired capital projects. This opportunity and long-term benefit justifies the addition of new end users including maintenance, safety, environmental, and reliability, in the FEED (Front-End Engineering and Design) of new projects. Additionally, by removing many of the physical constraints of wiring and power (as well as reduced weight), wireless networks provide new flexibility in project execution.

Ancillary device	Any device that does not contain a measuring sensor or output to the process for actuation.
Gateway	Enables communication between wireless field devices and host applications connected to an Ethernet, Serial, or other existing plant communications network; management of the wireless field network; and management of network security. Conceptually, the gateway is the wireless version of marshaling panels and junction boxes. The gateway functionality may also exist in native <i>WirelessHart</i> I/O cards with field radios
Host System	Any system accepting data produced by the <i>WirelessHART</i> Field Network (WFN). This could be a DCS, PLC, RTU, Data, Historian, asset management software, etc.
Join Key	A 128 bit security key used to authenticate wireless field devices when joining the network, including encryption of the

join request.

A common Join Key may be used among all devices on a given network, or each device may have a unique join key.

(Note: When displayed in hexadecimal format via a browser or handheld, this results in a 32 character hexadecimal field).

Network ID An integer between 0 and 36863 that distinguishes one *WirelessHart* network from another. Each gateway at a facility or location should be programmed with a unique Network ID. All authenticated wireless field devices with the same Network ID will communicate on the same network and gateway.

Update Rate The user specified interval at which a wireless field device will detect a measurement and transmit the measurement to the gateway (i.e. sample rate). The update rate has the largest impact on battery life due to the powering of the device sensor.

Update rate is independent of radio transmissions required for mesh peer-to-peer communication, “hopping” via multiple devices to transmit a measurement back to the gateway, and downstream communications from the host system to the wireless field device.

Wireless Adapter Enables an existing 4-20 mA, HART-enabled field device to become wireless. Adapters allow the existing 4-20 mA signal to operate simultaneously with the digital wireless signal.

Wireless Field Devices Field device enabled with a *WirelessHART* radio and software or an existing installed HART-enabled field device with an attached *WirelessHART* adapter.

Wireless Field Network A self-organized network of wireless field devices that automatically mitigate physical and RF obstacles in the process environment to provide necessary bandwidth for communicating process and device information in a secure and reliable way.

Wireless Repeater Any wireless field device used to strengthen a wireless field network (by adding additional communication paths) or expand the total area covered by a given mesh network.

3. SYMBOLS/ABBREVIATIONS

CSSP	Control Systems Security Program
DCS	Distributed Control System
DD	Device Descriptor
DSSS	Direct-Sequence Spread Spectrum
FAT	Factory Acceptance Test
FEED	Front End Engineering and Design
HMI	Human Machine Interface
LOS	Line of Sight
NFPA	National Fire Protection Association
PFD	Process Flow Diagram
P&ID	Piping and Instrument Design
PLC	Programmable Logic Controller
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
SIT	Site Integration Test
SPI	Serial Peripheral Interface
SPL	Smart Plant Layout
TSMP	Time Synchronized Mesh Protocol
TSSI	Temporal Single-System Interpretation
UDF	User Define Fields
WFN	<i>WirelessHART</i> Field Network

4. PROJECT CONCEPTS

XMTR-MV uses an INI file (installed in the WINNT/WINDOWS folder). The file contains important information that establishes the identity of the XMTR-MV device.

4.1 Pre-FEED

During the Pre-FEED phase, consideration must be given to available technologies and an assessment made as to the applicability to the specific project and application. It is during this Pre-FEED phase that *WirelessHART* should be considered as a candidate technology, along with other protocols including HART, Foundation Fieldbus, and Profibus.

During the Pre-FEED phase, spectrum approvals for the end-user and any intermediary locations should be verified. Refer to Appendix D Wireless Spectrum Governance for more details.

An integrated approach should be used for incorporating wireless into a project. Wireless should be merged with the established procedures for a wired project. The key consideration is to use the right field device technology for the right application and expand consideration for possibly new end user communities during the FEED process.

Right Technology for Right Application

WirelessHART is designed for both control and monitoring applications. Most current use cases emphasize monitoring applications due to conservative adoption of technology to meets the needs of a conservative industry. The use of wireless control applications is continuing to evolve with the introduction of discrete output devices for performing simple control functions. The table below provides a high level summary for selection of the right protocol when factoring in loop criticality; cost to engineer and implement; and location of field devices relative main process areas and host systems.

	Safety Systems	Control	In-Plant Monitoring	Remote Monitoring
Wired HART				
FOUNDATION Fieldbus				
<i>WirelessHART</i>				

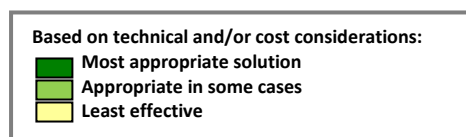


Figure 1. Selecting the Right Protocol

Technology Evaluation

The project should establish design rules to define which measurement and control points are *WirelessHART* appropriate in order to enable consistent and efficient engineering for subsequent project phases.

The technical authority will make a decision to use wireless based on the following high level criteria:

- Economic Assessment
- Potential applications
- Potential operational savings
- Potential benefit of new measurements providing additional process insight
- Benefits of adding measurement not previously considered feasible for inclusion in the automation system due to economics or practicality – example: monitored safety showers
- Benefits of flexibility in project execution – example: ease of moving or adding I/O points during construction to cost effectively manage onsite changes

The economics of installing field wiring has primarily limited the benefits of automation to process control and safety applications with additional points added over the life of the plant to resolve critical problems. Since *WirelessHART* does not require wires for communication or power, the financial hurdle rate that determines if a point is automated or not is redefined.

Special consideration should be given to understand the automation needs of new process plants to ensure they meet stricter safety, environmental, reliability and performance criteria. Below are a few examples:

- Many new plants are designed to operate with fewer personnel. Upgrading simple gauges to wireless field devices can automate the manual collection of data from the field in order to increase worker productivity and reduce exposure to hazardous environments.
- Many existing facilities have been modified in order to meet emerging environmental regulation. Real time monitoring of volatile organic compound release (VOC) from pressure safety valves and the conductivity and temperature of effluent waters can ensure environmental compliance.
- Remote monitoring of safety showers and gas detectors during construction and operation can provide new levels of safety response.
- New environmental regulation often requires redundant monitoring systems on assets like tanks that were not required in the past. *WirelessHART* can provide a cost effective, reliable secondary communication method and monitoring method.
- Monitoring of steam traps and heat exchangers can provide real time information for minimizing plant energy consumption.

Cost effective field information accessible via *WirelessHART* field devices enables non-traditional end users of automation to be considered in the FEED and Design Phases. A designer should be aware of initiatives for safety, environmental protection, energy consumption, and reliability in addition to the traditional considerations for process automation. *WirelessHART* provides a unified infrastructure for extending the benefits of automation to multiple plant initiatives without the need for multiple forms of I/O infrastructure.

4.2 FEED

Key deliverables exist for wireless in the FEED, for example: cost estimating, design guidelines, and specifications.

Cost Estimation

Vendors of *WirelessHART* field devices may have cost calculators and capital project studies that can be referenced and compared to support the cost justification of wireless into a project or an all wireless project. For a large capital project, wireless can reduce capital costs by switching wired monitoring points to wireless.

Design Engineers should assess and incorporate the following factors in their project cost estimating calculation model:

- Reduced engineering costs (including drawing and documentation, and Factory Acceptance Test (FAT))
- Reduced labor (field installation, commissioning, supervision)
- Reduced materials (terminations, junction boxes, wiring, cable trays/conduit/trunking, power supplies, and control system components)
- Reduced cost of change order management (including adding, removing, and moving field devices)
- Reduced project execution time (including commissioning of wireless field device simultaneously with construction)
- I/O capacity management (each *WirelessHart* gateway essentially provides spare I/O capacity)

Design Guidelines for *WirelessHART*

During the FEED process, all project stakeholders should be made aware of the capability and benefits of *WirelessHART* so that design engineers can identify potential candidate applications. The project should develop a wireless design and circulate to all project stakeholders.

For example, the process design engineer can use a set of criteria such as the simplified table in Figure 2 to identify candidate wireless applications.

	Safety Systems	Control	In-Plant Monitoring	Remote Monitoring
<i>WirelessHART</i>				

Based on technical and/or cost considerations:

- Most appropriate solution
- Appropriate in some cases
- Least effective

Figure 2. Example Criteria

Ideally, Candidate *WirelessHART* applications are identified during the early process design phase during FEED. This could be during Process Flow Diagram (PFD) and Piping and Instrument Design (P&ID) Diagram development. However, if an early decision is not taken this should not preclude the use of the technology later in the project.

The basis for design should be shared amongst all stakeholders so that other technical design authorities can identify potential wireless applications and benefit from the installed wireless infrastructure. Furthermore, this process ensures consistent implementation across all design authorities and allows for an efficient decision process to use wireless.

Points to consider when setting guidelines:

- Determine which categories of points are eligible to be wireless: safety, control, monitoring, and local indication.
- Determine if new users are eligible for automation: process efficiency, maintenance, reliability, asset protection, health/safety/environmental, and energy management.
- Determine percent spares required and necessary spare capacity.
- Factor in distance considerations between gateways and wireless field devices. Distance considerations are elaborated on in Section 7, Designing.

Specifications

Specifications for *WirelessHART* field devices are mostly the same as wired HART devices. See Appendix B *WirelessHART vs. Wired Hart Comparison* for key differences. HART instrumentation specifications are the foundation for *WirelessHART* specifications. The fundamental differences with regards to the ISA-20 specifications are output signal, power supply, update rate, protection type/enclosure. Specifications not included in this short list are either included with the IEC 62591 *WirelessHART* standard, small deviations from HART that require optional attention for the specification process, or are unique to a field device vendor.

Figure 3 is a comparison of fundamental differences in the specifications¹:

Specification Field	Typical HART Specification	Typical <i>WirelessHART</i> Specification
Output Signal	4-20 mA HART	IEC 62591 <i>WirelessHART</i>
Power Supply	24V DC Loop Powered	Intrinsically Safe Battery ²
Update rate	1 second	1 second to 60 minutes
Protection Type/Enclosure	Explosion Proof	Intrinsically Safe ²

Figure 3. Key Differences Between Wired and *WirelessHART*

IEC 62591 *WirelessHART* is an international standard for wireless process devices. The standard includes advanced provisions for security, protocol, and other features and therefore specification of such attributes covered in the standard are not necessary.

Appendix A provides example specifications for a *WirelessHART* gateway and wireless adapter that can be generically specified as transceivers/receivers.

4.3 Detailed Engineering

During the detailed engineering phase of a project, the engineer must account for *WirelessHART* devices per the guidelines established in the FEED, add wireless specific fields to the project database, and conduct wireless field network design procedures to ensure best practices are implemented.

Sort the Points

Using the wireless guidelines established in the FEED, the design engineer should do a sort of all points in the project database to identify which are eligible to be wireless. For example, if monitoring is deemed to be an eligible category, these points should be sorted from the control and other points. Afterwards, further requirements of the field devices can be applied. For example, some control and monitoring points may be excluded from wireless eligibility because the required update rate exceeds either the desired life of the battery or the capability of the field device.

Typical safety and control update rates may require 1 second or faster. There is a trade-off for wireless devices between update rate and battery life; the faster the update rate, the lower the battery life will be. The current recommendation is that an application should have a time constant satisfied by an update rate that supports a battery life of multiple years for reduced maintenance. However, faster update rates can be considered if the wireless device will be powered externally, an energy harvesting device, or if battery maintenance is not a concern for that application. Additionally, it is recommended that the update rate of the measurement be three times faster the process time constant. As an example, a typical update rate for measuring temperature changes with a sensor inside a thermowell can be 16 seconds or longer given how much time is required for heat to penetrate the thermowell.

Database Field for Wireless Network Assignment

Each wireless field device must be assigned to a specific gateway that manages a specific wireless field

¹ Values in table are typical and representative.

² The trend with wireless field device vendors has been to provide intrinsically safe protection. This difference is noted in the best interest of the reader to support due diligence.

network. There must be a corresponding field that indicates the association of the field devices to the gateway. Without this information, the wireless field device will not be able to receive the proper security information to join the intended wireless field network nor the proper integration into the host system from the gateway.

Each gateway will manage its own wireless field network and can have an assigned HART Tag like any HART device. Each wireless field network in a plant must have a unique Network ID to prevent devices from attempting to join the wrong network. In order to ensure the desired security level is achieved, a decision must be made whether to use a common join key for all devices in a given field network, or unique join keys for each field device. The combination of these two parameters provides identification and authentication down to the field device. Below are examples of a gateway HART TAG, Network ID and Common Device Join Key.

Parameter	Parameter Options	Example	Technical Details
Gateway HART TAG	Field	UNIT_A_UA_100	32 characters – any in ISO Latin-1 (ISO 8859-1) character set.
Network ID	Integer	10145	Integer between 0 and 36863

Figure 4. Definitions of Network Parameters When Using a Common Join Key

The Join Key is the most important parameter for implementing security. A user can know the Gateway HART TAG and the Network ID for the network the gateway manages, but without a Join Key, a wireless field device cannot join the network. The design engineer should be sensitive to the security policies of the design firm and the security policies of the future owner/operator and, as a minimum, treat the Join Key with the same sensitivities as a password for a server to a DCS or database. For this reason, storing the join key as a field in a design database is not prudent.

Fields should be added to the project database to indicate that a field device is wireless and its association with a gateway using the gateway HART TAG or other labeling convention. Parameters required to be managed confidentially should be controlled in a secure means in alignment with established security policies. Staff members with IT security or process security responsibilities are well suited to provide consultation into the handling of sensitive information.

Finally, the design engineer should be aware of available *WirelessHART* devices. Many come with multiple inputs that can satisfy the total number of points in a project with fewer devices. For example, several vendors have a multiplexed *WirelessHART* temperature device that reduces costs.

Network Design

Once wireless candidate devices have been identified in the instrument database the field network design can begin.

Ideally wireless points should be organized by process unit and by subsection of process unit as typically depicted in a master drawing. This information can be used to determine the number of gateways required. Additional gateways can be added to ensure spare I/O capacity per guidelines or other project requirements. From here, the gateways should be logically distributed throughout the process unit like marshaling panels. Wireless field devices should then be assigned according to which gateway is closest or

by which gateway is assigned to the process unit subsection in which the field devices reside. Once this is complete, network design best practices should be checked to ensure the network will be reliable. This will be covered in detail in the *WirelessHART* Field Network Design Guidelines.

Drawings should be created per existing standards. In most instances, a wireless field device is treated identically to a wired HART device. Most drawings do not indicate wires or the type of communication protocol, thus nothing unique needs to be done for wireless field devices. The section on Ancillary Device Requirements provides examples unique to *WirelessHART* such as gateways and wireless adapters. Fundamentally, it will be up to the design engineer to adhere to or provide a consistent convention that meets the needs of the contractor and the owner operator as is true for wired HART projects.

Existing HMI (human-machine interface) design guidelines for integration also apply to wireless with no change required since data points connected from the gateway into the host system are managed like any other source of data.

Factory Acceptance Test

Factory Acceptance Tests require establishing a connection between the Gateway and the Host Systems. *WirelessHART* gateways typically have standard output communication protocols that directly connect to any host system. The design team should keep a library of these integration options for reference.

Installation

In general, *WirelessHART* device are installed exactly like wired HART devices. Emphasis should always be placed on making the best possible process connection for accurate measurement. The self-organizing mesh technology in *WirelessHART* enables wireless field devices to self-route through the process environment and reroute when the environment changes. Always consult the instruction manual of the *WirelessHART* device for specific considerations. This is covered in detail in *WirelessHART* Field Network Design Guidelines.

WirelessHART adapters are typically installed on an existing HART enabled device or somewhere along its 4-20 mA loop. Always consult the manual of the *WirelessHART* adapter for specific considerations.

WirelessHART gateways are typically placed 6 feet (2 meters) above the process infrastructure (typically above cable trays) and located in the process unit where the maximum number of direct connections with wireless field devices can be achieved. Gateways may have an integrated or remote antenna for installation flexibility.

WirelessHART repeaters are typically mounted 6 feet (2 meters) above the process infrastructure and should be located in areas of the wireless network that need additional connectivity.

It is recommended to install the gateway first in order to allow host system integration and wireless field device installation and commissioning to commence in parallel. Wireless field devices can be commissioned as soon as process connections are in place and a device is joined to a network. Once the wireless device is activated with proper configuration, update rate, and security provisions for Network ID and Join Key, it will form a network that compensates for the current condition of the process unit and will adapt as the unit is built. The project manager can have wireless device installation occur in parallel with construction to maximize project time buffers or pull in the project completion date.

Commissioning

WirelessHART gateways segment the commissioning process. Since gateways connect the wireless field devices to the host system, *WirelessHART* devices can be commissioned to the gateway to ensure proper

connectivity independently of verifying integration into the host system. A wireless loop check can confirm connectivity from the wireless field device through the gateway to the host system. Interaction with the process and the *WirelessHART* device can confirm the device is operational.

5. DOCUMENT REQUIREMENTS

5.1 Drawings

Every project will require the establishment of local standards for implementing consistent documentation.

See Documenting in Intergraph SPI 2009 for a complete treatment of documentation.

5.2 ISA Documentation

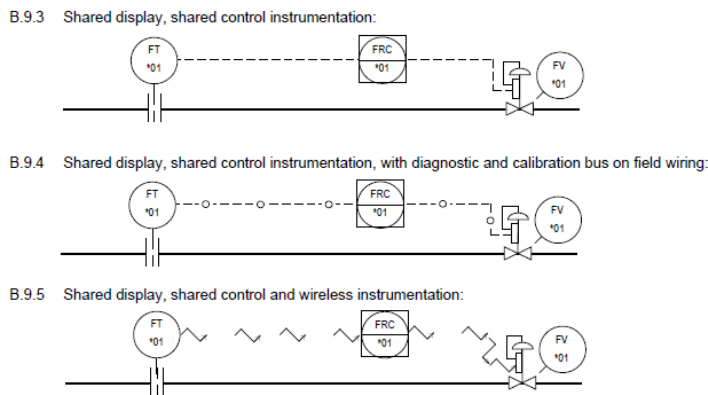
The American National Standard document ANSI/ISA-5.1-2009: Instrumentation Symbols and Identification, approved on September 2009, provides basic guidelines for wireless instrumentation and signals.

Key points:

There is no difference in the symbol between a HART, FF, and a *WirelessHART* device. An instrument is an instrument.

The line style for indicating a wireless signal is a zig zag and not a dash.

Below is an image from the ISA-5.1 document showing some comparative examples. Please reference ISA-5.1 for complete details.



3

Figure 5. ISA 5.1 Wireless Drawing

The implementation of *WirelessHART* requires far fewer components, making drawings simpler.

³ ISA-5.1

5.3 Control Narrative

Define in the FEED phase and ensure this is implemented with design guidelines.

5.4 Instrument Index/Database

See Documenting in Integraph SPI 2009 for recommendations for additional fields not typically included in wired HART specifications.

5.5 Instrument Data Sheets

Use standard data sheets created for wired HART devices. Update the following fields to reflect *WirelessHART*:

Specification Field	Typical Value
Update rate	1, 2,4, 8, 16, 32, 64+
Power Supply	Intrinsically safe, field replaceable battery
Communication Type	IEC 62591 <i>WirelessHART</i>

Figure 6. *WirelessHart* Specifications For Instrument Data Sheets

No special ISA or other specification sheets are required as the same sheets can be used to specify HART, FOUNDATION Fieldbus, or *WirelessHART*. See Appendix A for a specification sheet example for a *WirelessHART* gateway.

5.6 Material Requisitions

Given the need for security and RF emissions, vendors must acquire approvals for importation to the country of end-use for compliance with local spectrum regulation and encryption regulation. The vendor can verify whether importation compliance exists for any given country.

The batteries are commonly made using a high energy compound using Lithium Thionyl Chloride. The Material Safety Data Sheet or equivalent should always be available as well as awareness of any shipping restriction; notably most countries do not allow the transportation of lithium batteries on passenger aircraft.

5.7 Manufacturer Documentation

Every *WirelessHART* device should have the proper documentation, including manual, as would be expected with a wired HART device.

5.8 Project Management

Subcontractor Scope Management

Wireless enables simplified subcontractor scope management. Packages can be easily tested and commissioned separately, requiring only minimal integration and testing to occur. Additionally the subcontractors will also benefit from fewer components and engineering. Tender contracts should be amended to recognize reduced complexity and eliminated work.

Project Scheduling

1. Review schedules to recognize:
 - Limited infrastructure installation and hence reduced material and installation scope
 - Remove some electrical and instrumentation checkout processes
2. Amend contracts to reflect simplified installation handover processes
3. Simplify installation schedule management
4. Reduce material coordination management and simplified construction schedule
 - Eliminated scheduling and expediting associated with marshaling cabinets
5. Schedule should reflect eliminated activities and simplified FAT, SAT and SIT (site integration test) on areas where wireless has been extensively deployed

Responsibility and Skills Matrix

Amend Roles and Responsibility matrix to reflect reduced/eliminated responsibilities

Ensure engagement of all project stakeholders/sub-contractor so that wireless can be applied efficiently to improve schedule and material costs

Managing Project Variations

For project change orders and other late design changes, wireless should be considered as the primary solution unless other design considerations exist. Using wireless will result in the fewest changes to the documentation, I/O layout and other detailed design as well as faster commissioning since you can move wireless devices without having to also re-engineer the wiring.

6. FIELD DEVICE REQUIREMENTS

6.1 Support for *WirelessHART* Functionality

All *WirelessHART* devices support methods to allow remote access to device configuration, backwards compatibility with existing field communicators, full implementation of *WirelessHART* security provisions, and *WirelessHART* interoperability.

6.2 Device Diagnostics

HART Diagnostics

WirelessHART devices contain similar or a subset all of the diagnostics of wired HART devices. Expect configurable alarms and alerts for both the process, the device, and the battery. Diagnostics information should be available through HART commands as well as accessible through Device Descriptions (DD) either locally through a field communicator or remotely using asset management software.

Wireless Field Device Network Diagnostics

Every *WirelessHART* field device should have diagnostics that indicate if a device is connected to a network or not.

Wireless Field Device Power Diagnostics

Wireless field devices may have one of three power options: battery, energy harvesting (including solar), or line power. Batteries will have a life determined by the update rate of the wireless field device, network routing for other wireless field devices, and efficiencies of the sensor and electronics. Typically, the primary consumer of power is the process sensor and electronics in the wireless field device. Using the *WirelessHART* radio or acting as a repeater for other *WirelessHART* field devices requires minimal power. Wireless field devices report their battery voltage and have integrated low voltage alarms such that the user can either schedule maintenance or take a corrective action.

Gateway Network Diagnostics

Gateway network diagnostics should indicate whether field devices are connected and functioning properly, and if devices are missing from the network. In order to be connected properly, proper bandwidth must be allocated based on the update rate of the device. A device connected but with service denied may indicate a device has an update rate that is too fast for the network capability or the network conditions. With gateways capable of holding 100 devices or more, clear indication of device availability is crucial.

Additionally, gateways should be able to detect, regardless of host system integration, the connectedness of a wireless field device. This information should be continually updated and indicate if a device is not connected for network or device reasons. Simple device states should be made available for integration into the host system regardless of output protocol from the gateway to indicate online/offline status.

6.3 Field Device Power

Wireless field devices may have one of three power options: battery, energy harvesting (including solar), or line power and there may be several options within each category.

Batteries

The most common will be the use of a battery for low power field devices due to ease of deployment. Most vendors will use battery cells incorporating Lithium Thionyl Chloride chemistry since it has the highest energy density, longest shelf life, and widest working temperatures that are commercially viable. Although typical cells look like battery cells for consumer electronics, precautions should be taken to ensure batteries are safely transported and introduced into the process environment. Refer to vendor documentation for safe handling practices.

Below are requirements for batteries:

- Batteries cells should be assembled by a manufacturer into a battery module to ensure safe handling and transportation.
- Battery module should prevent a depleted cell being introduced in circuit with a charged cell, which can cause unintended electrical currents and heat.
- Battery module should provide ease of replacement. Battery replacement should take minimal time and training.

- Battery module should be intrinsically safe and not require removal of the wireless field device for replacement.
- Battery module should prevent intended and unintended short-circuiting that could lead to heat or spark.
- Battery module should be designed for the process environment with mechanical properties that provide drop protection and operation over normal process temperatures expected for devices.
- Battery modules should come with necessary Material Safety Data Sheets (or equivalent) and warnings and be disposable per local governmental regulation.
- Battery module should not be capable of connecting to consumer electronics or non-designed applications to prevent a high-capacity supply from being connected to incompatible electrical systems.
- Battery modules should be applicable to several *WirelessHART* field devices to maximize inventory management efficiencies in the local warehouse for spare parts.

The design engineers of the wireless field network and end users should use update rates that maximize the life of the battery module and minimize maintenance.

Energy Harvesting

Vendors may provide energy harvesting options as alternatives to batteries that may include solar, thermal, vibration, and wind solutions. Current energy conversion techniques for thermal and vibration are relatively inefficient. In many cases, energy harvesting solutions also utilize rechargeable batteries to maintain constant back-up power supply. Today's rechargeable batteries have a life expectancy of only several years during which they can maintain a full charge and are often sensitive to temperature change for supplying power and recharging

Below are requirements for energy harvesters:

- Energy harvesting device should have a designed connection to the wireless field device.
- Energy harvesting device should have means for providing multiple days of back-up power in the event the energy source is discontinued for several days.
- Energy harvesting device should be mounted such that it is not negatively impacted by changes in the season, process conditions, and according the vendor recommendations.
- Energy device should be intrinsically safe and installation should follow local practices for low voltage wiring.
- Energy harvester should have the means for the user to know the state of the device via the wireless field device.
- The lifetime and maintenance of rechargeable batteries should be understood and incorporated into a maintenance routine.

Wired Power

A wired power option for wireless field devices is an emerging option from vendors since the cost of local power can be less than the cost of a control signal wire with power or a power module. Some *WirelessHART* Adapters may harvest power off of the 4-20 mA loop to wired HART device. Some applications with high power sensors may need to be wireless to meet a communications specification, but require more power than a battery or energy harvester can provide.

Below are the requirements for a wired power option:

- *WirelessHART* adapters harvesting power from the 4-20 mA signal of the wired device should not affect the 4-20 mA signal during normal operation or failure mode.
- Low voltage powered wireless devices (<30 VDC) should be capable of operating over a range of voltages – example: 8-28V using standard low voltage wiring practices.
- Wired powered option may require the use of Intrinsically Safe barriers between the DC voltage source and the wireless field device.

6.4 Field Device Security

Security is a new consideration for wireless field devices that is driven by an increased focus on the protection of critical infrastructure by governments and other security authorities.

Below are the requirements for wireless field device security:

- Wireless devices should be compliant with all *WirelessHART* security provisions including correct usage of Network ID and Join Key.
- The user or unintended user should not be able to physically or digitally read the Join Key from the wireless device. The Join Key(s) should be treated as confidential and subject to the requirements of any local security policy.
- The wireless device should be receptive to security changes initiated by the gateway, including Network ID, Join Key, and the network, session, and broadcast keys that validate packets sent through the network and prevent tampering and eavesdropping.
- The gateway and any management program connected to the *WirelessHART* network through the gateway should protect all security parameters according to a local security policy.
- Wireless field devices should not have a TCP/IP address in order implement a layered security policy. The exception is the gateway with a TCP/IP connection to the host system via a firewall.

6.5 Approvals

Every *WirelessHART* device must have the appropriate hazardous area approval to meet the conditions of the process environment as well as the appropriate spectrum and encryption approvals. Spectrum and encryption of wireless signals are regulated by government agencies, such as the FCC in the United States. Typically, verifying with the *WirelessHART* device manufacturer that the device has proper approval for importation into the country of usage is sufficient. Spectrum and encryption approval are a procurement issue and do not represent a design parameter like a hazardous area approval.

6.6 Accessibility

WirelessHART devices are subject to the same mechanical and electrical specifications as wired HART devices is they operate in the same process environments.

Below are general requirements for *WirelessHART* field devices:

- *WirelessHART* devices shall be locally accessible with HART field communicators that support wired and *WirelessHART* devices.
- *WirelessHART* devices shall be manageable with remote asset management systems that access the *WirelessHART* device via the gateway and through the *WirelessHART* network.
- *WirelessHART* adapters shall extend the benefits of a *WirelessHART* network to wired HART devices that may or may not be operated on a 4-20 mA loop.

7. ANCILLARY DEVICE REQUIREMENTS

An ancillary device is defined as any device that does not contain a measuring sensor or output to the process for actuation. These include wireless gateways, local indicators, wireless repeaters and/or *WirelessHART* adapters.

7.1 Gateways

The gateway enables communication between wireless field devices and host systems connected to an Ethernet, serial, or other existing plant communications network. *WirelessHART* manufacturers have typically chosen to integrate the network manager, security manager and access point functionalities into one product. Conceptually, the gateway is the wireless version of marshaling panels and junction boxes.

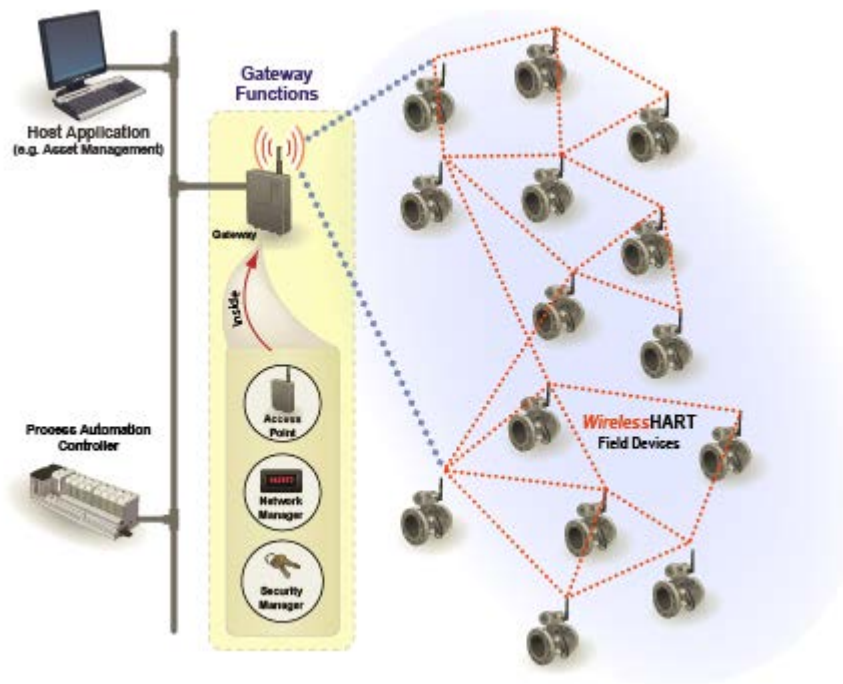


Figure 7. Gateway System Architecture

Below are the requirements for a *WirelessHART* gateway:

- The gateway should provide an easy to manage solution for enabling gateway, network management, and security management functionality
- Gateway should have controlled access for a security policy. Gateway should have multiple user accounts with differing access to critical security and configuration parameters such that there can be secure network administration.
- Gateway should have multiple output protocols to ensure integration to a range of host applications. In any given process facility, there can several types of DCS, PLC, and data historians requiring multiple protocols. Multiple output protocols allow convenient connectivity with a standard gateway.
- The gateway should support multiple connections and, in effect, act like a server. Typical *WirelessHART* applications require data to be sent to multiple host applications in order to provide data to multiple end users.
- The gateway should support the secure transfer of all protocols over an Ethernet connection through a robust encryption process.
- Gateway should be interoperable and support the network management of *WirelessHART* devices from multiple vendors.

7.2 Wireless Repeaters

There are no special requirements for a *WirelessHART* repeater. If a repeater is a *WirelessHART* device with a configurable update rate, then minimizing the update rate shall maximize the life of the battery module without impacting the network reliability.

If a vendor chooses to develop a *WirelessHART* device for the specific purpose of acting as a repeater, then that repeating device should be managed like any other *WirelessHART* device and subject to all the specifications of a *WirelessHART* device. *WirelessHART* adapters can be used effectively as repeaters if local power or a wired HART device is available.

7.3 *WirelessHART* Adapters

WirelessHART adapters connect to wired HART devices that are not inherently wireless and provide parallel communication paths through the 4-20 mA loop and the *WirelessHART* field network. There are four main use cases for *WirelessHART* adapters:

- Access HART diagnostics that are not accessible due to limitations of the host system which may not detect the HART signal on the the 4-20 mA loop.
- Provide wireless communications for HART devices which are not natively wireless.
- Enable device information to be accessed by multiple users who may not have direct access to the control system. In this scenario, the 4-20 mA signal is sent to the control room while the *WirelessHART* signal is used to access parametric and diagnostics data by maintenance or other personnel.
- Act as a wireless repeater.
- Below are the *WirelessHART* Adapter specifications:
- Adapter should not affect the 4-20 mA signals under normal operation or in failure mode.
- Adapter should operate like any other *WirelessHART* field device in the *WirelessHART* field network.
- Adapter should have a HART Tag.
- Adapter should pass through the wired HART device process variable as well as remote access for configuration and calibration.
- Adapter should employ the same security functions and methods as a standard *WirelessHART* device.

8. WIRELESSHART FIELD NETWORK

8.1 Design Guidelines

The *WirelessHART* network specification enables a reliable, secure, and scalable architecture. Contrary to legacy systems and point-to-point wireless networks, *WirelessHART* is a truly scalable automation technology that gets more robust as more devices are added to an existing network. Design guidelines support the deployment of small networks with less than 10 *WirelessHART* devices for monitoring and control, as well as installations supporting thousands of devices.

This section includes recommendations to support the long-term, sustainable adoption of wireless applications including *WirelessHART* as well as Wi-Fi, Wi-Max, and more.

The best practices for network design are applicable for networks operating with mix of *WirelessHART* devices for monitoring and control with update rates from 4 seconds to 3600 seconds (60 minutes). Please see the section Designing for Control for additional considerations when including 1 second update rates.

A site survey is not normally required or even possible in the case of a Greenfield site. For an overview on spectrum usage refer to Appendix D Wireless Spectrum Governance.

8.2 Wireless Project Overview

An extensive summary of the project overview was previously discussed in Project Concepts.

WirelessHART is built upon the HART standard; therefore minimum differences exist between the usages of wired and wireless devices. The minimal need for wires also means there are fewer engineering details to manage and fewer engineering parameters to introduce. This section provides a thorough discussion of *WirelessHART* Field Network Design.

The following can be applied to small projects requiring a single gateway or a large project requiring several gateways.

8.3 *WirelessHART* Field Network Design

There are three key steps for designing a network:

- Scope – Decide if you need to divide wireless field networks by process unit or subsection of a process unit. Factors include:
 - Number of devices in the process unit
 - Update rates need for wireless devices
 - Capacity of gateway
- Design – Apply design rules to ensure optimum connectivity.
- Fortify – Identify and correct any potential weaknesses in the network design.

The three basic steps apply for all process environments in all industries, although the context may vary slightly depending on the physical structure of the process environment. The basic steps also apply regardless of the vendor of the *WirelessHART* device. Since *WirelessHART* networks become stronger the more devices are added, the Scope step is the most critical for high density applications.

WirelessHART is designed for both control and monitoring. Recommendations for using wireless control are discussed on Pg. 11 in Project Concepts. *WirelessHART* is the most appropriate communications protocol for many monitoring and some control applications when considering the overall cost and technical considerations. In general, control with *WirelessHART* is appropriate for most cases of open loop control that would require manual interaction with the process and some cases of supervisory control for set point manipulation and process optimization. Applications for closed loop regulatory control of a critical loop may be evaluated case by case.

8.4 Design Resources

See the Design Resources Appendix for more information. Contact your respective *WirelessHART* vendor for automated design tools to aid:

- Network Design
- Gateway Capacity Planning
- Device Type Availability and Battery Life Estimation

8.5 Scoping

The same design rules that govern the segmentation of wired HART networks apply to *WirelessHART*. From a very simple perspective, all process facilities have an architecture that organizes the infrastructure as well as the automation and the people. *WirelessHART* not only self-organizes to the process environment, but also to this inherent organization of the process facility. For example, the process facility shown in Figure 8 is organized into 7 process units that are separated by roads.

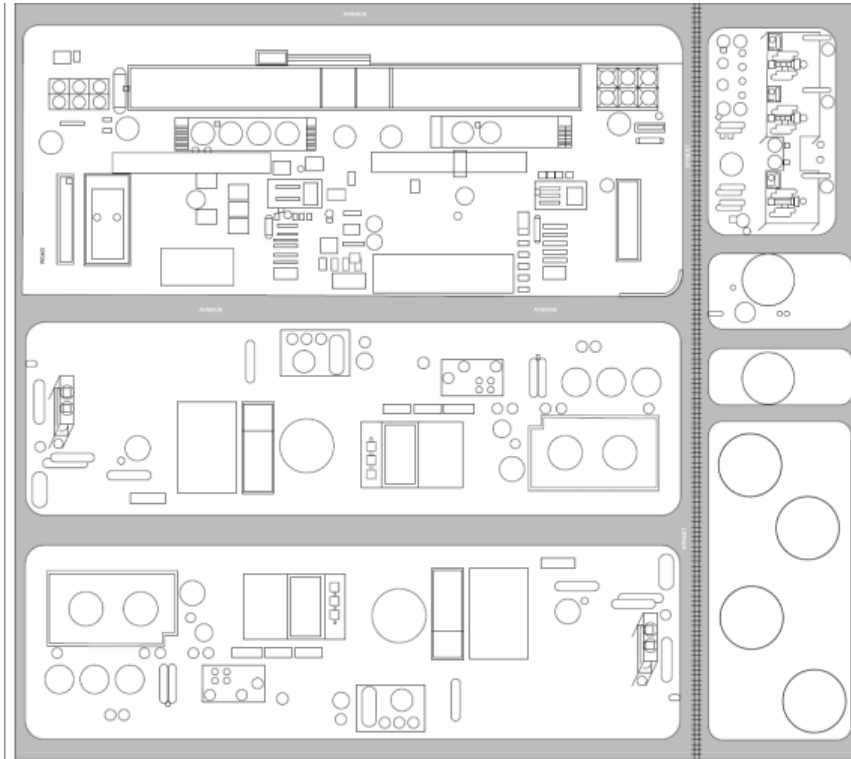


Figure 8. Example Process Facility

If the process facility is not an outdoor production environment, there is still a natural organization that should be used for scoping networks. For example, power plants and biopharmaceutical manufacturing facilities are typically completely enclosed with multiple floors. One option is to scope *WirelessHART* field networks to a floor. If there are 7 floors, then there are potentially seven *WirelessHART* networks.

The benefits of scoping a *WirelessHART* field network to a process unit are:

- Aligns the data flow from the *WirelessHART* device through the gateway to the Host System with existing data architecture.
- Aligns *WirelessHART* tagging convention with wired HART tagging convention.
- Aligns *WirelessHART* documentation practices with the process unit and support device location. If you know device A is on Network A and in process unit A, then one should not look in process unit B to find device A.
- Aligns work processes of managing *WirelessHART* device lifecycles with wired HART life cycles including organizational responsibilities.
- Sets reasonable expectations for range between *WirelessHART* devices. Most process units do not have a footprint greater than a few hundred feet (<0.2km) by a few hundred feet (<0.2km).

While scoping the number of networks and gateway placement, the design engineer should factor in considerations for gateway capacity and spare capacity. At a minimum, each process unit should have

its own gateway with spare capacity for problem solving in real time. If a project is small and application focused, then typically a single gateway is required if the total number of points is less than the capacity of the gateway. If the project is large or has wireless field devices with update rates faster than 4 seconds, then following is the process of determining the total number of gateways and modifying the scope of a network.

1. Filter the Instrument Index List by process unit and determine how many I/O points are in each process unit that are wireless so that the *WirelessHART* networks can be segmented by process unit.
 - a. For example, out of 700 total I/O points, let's assume process unit A has 154 wireless points requiring 154 *WirelessHART* devices. We need to determine how many gateways are needed. Note that some *WirelessHART* devices support more than 1 wireless point and so there may be instances when fewer devices are required to satisfy the number of measurement points. A key example is a *WirelessHART* temperature transmitter where 2 or more temperature elements are used as inputs.
2. Identify the necessary update rate of each *WirelessHART* device to meet the specifications of the application as well as battery life.
 - a. Typical *WirelessHART* devices can update from 1 per second to once per hour.
 - b. Update rate should be 3-4 times faster than the time constant of the process for monitoring and open loop control applications.
 - c. Update rate should be 4-10 times faster than the time constant of the process for regulatory closed loop control and some types of supervisory control.
 - d. The faster the update rate, the shorter the battery life. Use an update rate that meets the needs of the application, but does not oversample in order to maximize battery life.
 - e. Update rates faster than 4 seconds can impact the total number of wireless devices that can be put on a gateway. Consult the specification of the gateway vendor for additional constraints and consultation.
3. Determine the capacity of the gateway determined by the maximum update rate to be used in the network. Be conservative and assume all devices are operating at the same, fastest update rate network for the purpose of estimation. Example output: 100 *WirelessHART* devices per gateway if all devices are updating every 8 seconds or slower and the gateway can support 100 devices at 8 seconds.
 - a. Note that some gateway vendors have advanced capacity planners that can provide detailed capacity estimate based on the required updates of individual update rates. *WirelessHART* networks can support a mix of device types and update rates. The method outlined here is a simple method that determines max capacity with very limited design information.

- Determine and apply any guidelines on spare capacity. If the design rules for the project state I/O components should have 40% spare capacity, then note this value for the following calculation.
- Use the following calculation to determine the number of gateways needed:

$$xy = \text{ROUNDUP}\left(\frac{\text{Total WirelessHART devices in process unit}}{\text{gateway capacity} * (1 - \text{spare capacity requirement})}\right)$$

For the example above, three gateways are needed.

$$\#gateway = \text{ROUNDUP}\left(\frac{154}{100 * (1 - 0.40)}\right) = 3$$

This formula can be entered into Microsoft Excel.

- Scope the number of required gateways into subsections of the process unit. If more than one gateway is needed per process unit, then the design engineer should segment the networks such that the gateways are distributed in the field like marshaling panels and junction boxes. In Figure 9, the master drawing, the process unit has 16 subsections labeled L-2 through L-17 that should be logically segmented for coverage by gateways. Not every gateway needs to have the same number of wireless points. If redundant gateways are to be used, then double the number of gateways based on the output from the above formula.

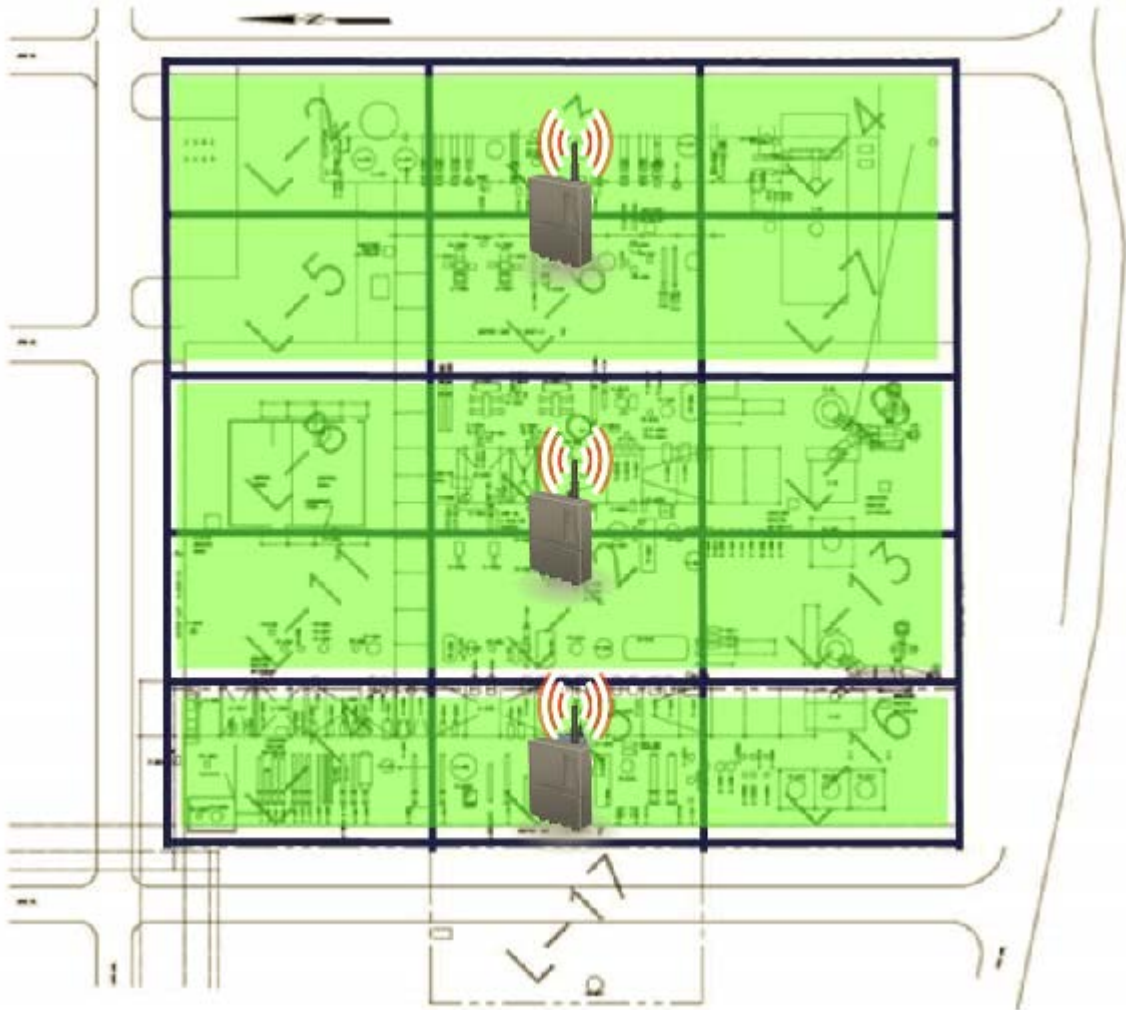


Figure 9. Example Process with 3 *WirelessHART* Networks and good gateway placement.

This example shows three *WirelessHART* gateways supporting three *WirelessHART* networks in the same process. This is analogous to having three FOUNDATION Fieldbus segments in the same process unit. In this example, the process unit subsections were grouped horizontally instead of vertically to minimize the distance of the process unit. A key consideration is that the gateways, regardless of manufacturer should always be in the process space for which they supply I/O capacity. Below is an image of what not to do:

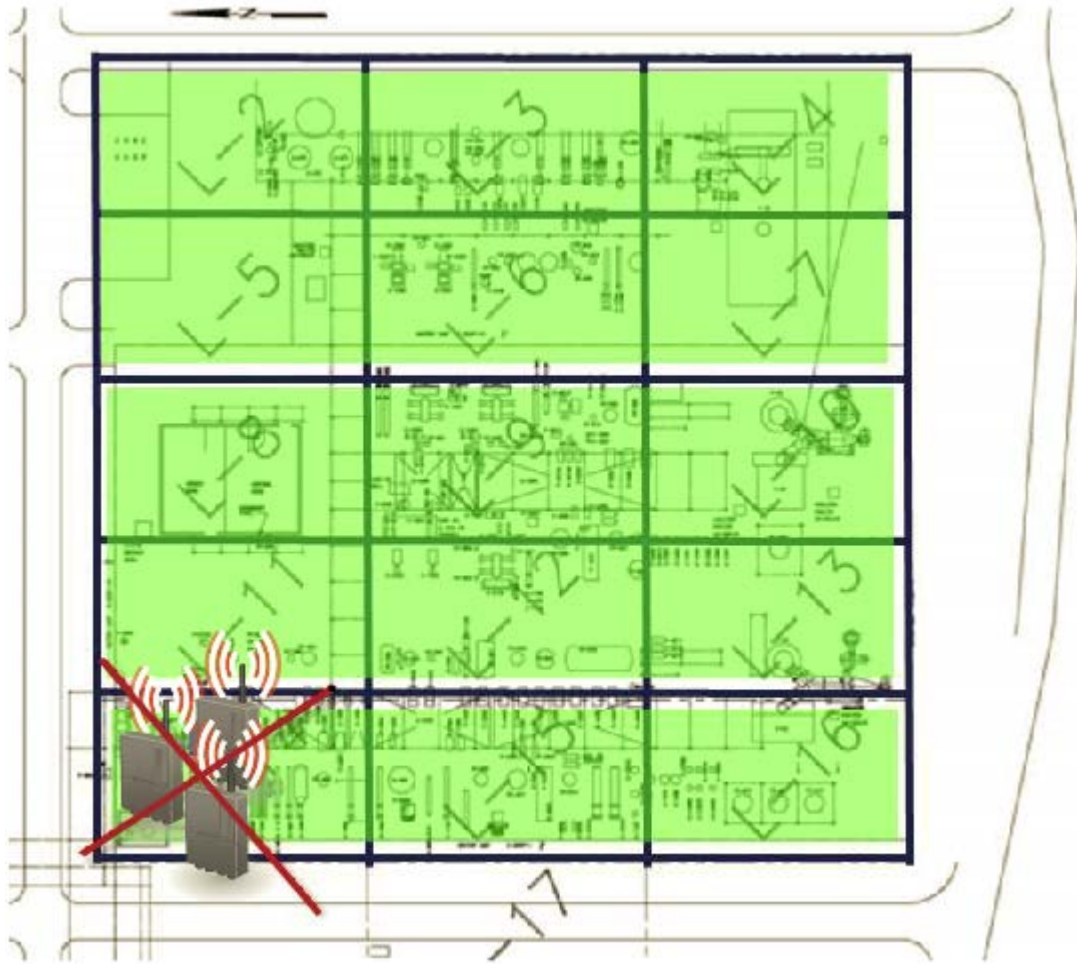


Figure 10. Example Process with 3 *WirelessHART* gateways and poor gateway placement.

Do not place all gateways in the same location just because connecting into the host system is convenient. The next section on network design will show this is inefficient and can lead to unreliable networks in the long term. The gateway should be centralized to the field network to maximize the number of connections to wireless devices.

WirelessHART networks can be logically aligned with existing documentation and automation engineering practices following this procedure.

Key things to remember:

- Scoping is the most important design rule. Use it to ensure wireless capacity, long term scalability, high reliability, and alignment of *WirelessHART* devices and management with existing process facility, organization, and work practices.
- Every *WirelessHART* gateway in a facility must have a unique Network ID to properly segment the *WirelessHART* field networks.

- The output from the scoping phase should be a scaled drawing showing the relative locations of assets and processes to be automated and potential integration points for the *WirelessHART* gateways.

8.6 Designing

Effective Device Range

The following design rules are intended to be very conservative and are based on real-world deployments of *WirelessHART* field networks. The effective range of a device is the typical linear distance between *WirelessHART* field devices when in the presence of process infrastructure. Typically, if *WirelessHART* devices have no obstructions between them, have clear line of sight (LOS), and are mounted at least 6 feet (2 meters) above the ground, then the effective range with 10 mW/10 dBi of power is approximately 750 feet (228 m). Obstructions decrease the effective range. Most process environments have high concentrations of metal that reflect RF signals in a non-predictable manner bouncing the signal off of the metal of the surrounding environment. The path of an RF signal could easily be 750 feet (230m) even though the neighboring device separation is only 100 feet (31m) away. Below are three basic classifications for effective range in the process environment:

- **Heavy Obstruction** – 100 ft. (30 m). This is the typical heavy density plant environment. Cannot drive a truck or equipment through.
- **Medium Obstruction** – 250 ft (76 m). This is the less light process areas, lots of space between equipment and infrastructure.
- **Light Obstruction** – 500 ft (152 m). Typical of tank farms. Despite tanks being big obstructions themselves, lots of space between and above makes for good RF propagation.
- **Clear Line of Site** – 750 ft (228 m). The antenna for the device is mounted above obstructions and the angle of the terrain change is less than 5 degrees. Some *WirelessHART* vendors provide options and techniques for obtaining even further distances for long distance applications.

These values are practical guidelines and are subject to change in different types of process environments. Conditions that significantly reduce effective range are:

- Mounting field devices close to the ground, below ground, or under water. The RF signal is absorbed and does not propagate.
- Mounting field devices inside or outside of a building relative to the main network and gateway. RF signals do not propagate well through concrete, wood, etc. Typically, if there are wireless devices nearby on the other side of the enclosure, no special design rules are needed. If there is a high volume of *WirelessHART* devices isolated from the network by a enclosure, consider scoping a network inside of the facility. Small, fiberglass instrument and device enclosures often deployed in very dirty or harsh environments show minimal impact on propagation of RF signal and can be used. Large Hoffman-style metal enclosures will prevent RF signals and are not recommended without additional engineering considerations.

The low power nature of *WirelessHART* devices allow operation for several years without replacing a battery module, but also limit the output power of the radio and maximum range. Because *WirelessHART*

devices can communicate through each other to send messages to the gateway, the self-organizing mesh naturally extends the range beyond that of its own radio. For example, a wireless device may be several hundred feet or meters away from the gateway, but power efficient “hops” through neighboring devices closer to the gateway ensure reliable, extended range.

The effective range is used to test the validity of network design by applying the following design rules.

There are 4 fundamental, recommended network design rules.

1. **Rule of 5 minimum** – Every *WirelessHART* network should have a minimum of 5 *WirelessHART* devices within effective range of the gateway. Networks will work properly with less than 5 *WirelessHART* devices but will not benefit from the intrinsic redundancy of a self-organizing mesh network and may require repeaters. In a well formed, well designed network, new *WirelessHART* devices can be added to the interior or perimeter of the network without affecting operation or extensive consideration for design.

Figure 11 is a simple design example. The network has been properly scoped to a process unit and 4 *WirelessHART* devices have been placed with a gateway on a scaled process drawing. The red circle around the gateway represents the effective range of the gateway. We see in this example, the Rule of 5 Minimum is broken in that there are only 4 devices within effective range of the gateway. This network will likely perform to specification, but it is optimal to fortify for long term scalability and reliability by adding more devices.

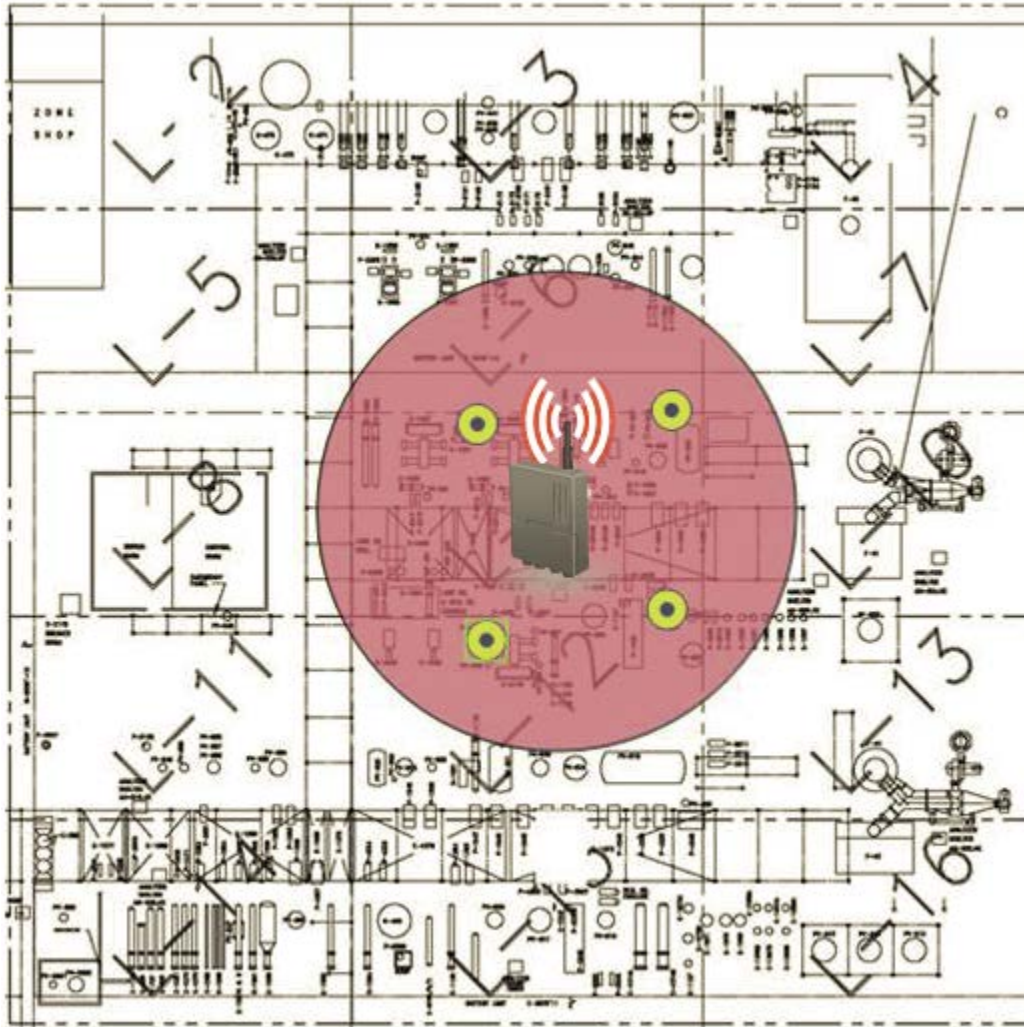


Figure 11. Example Process With Rule of 5 Broken

2. **Rule of 3** – Every *WirelessHART* device should have a minimum of 3 neighbors within effective range. This ensures there will be at least 2 connections and the potential for connections to change with time.

Continuing on from the previous example, we fortified the network by adding another field device within the effective range of the gateway and added another device as another measurement point. Now the red circle represents the effective range of the *WirelessHART* device that does not have 3 neighbors. For reliability, it is essential for every *WirelessHART* to have 2 paths during operation to ensure a path of redundancy and diversity. The Rule of 3 when designing ensures concentration of devices.

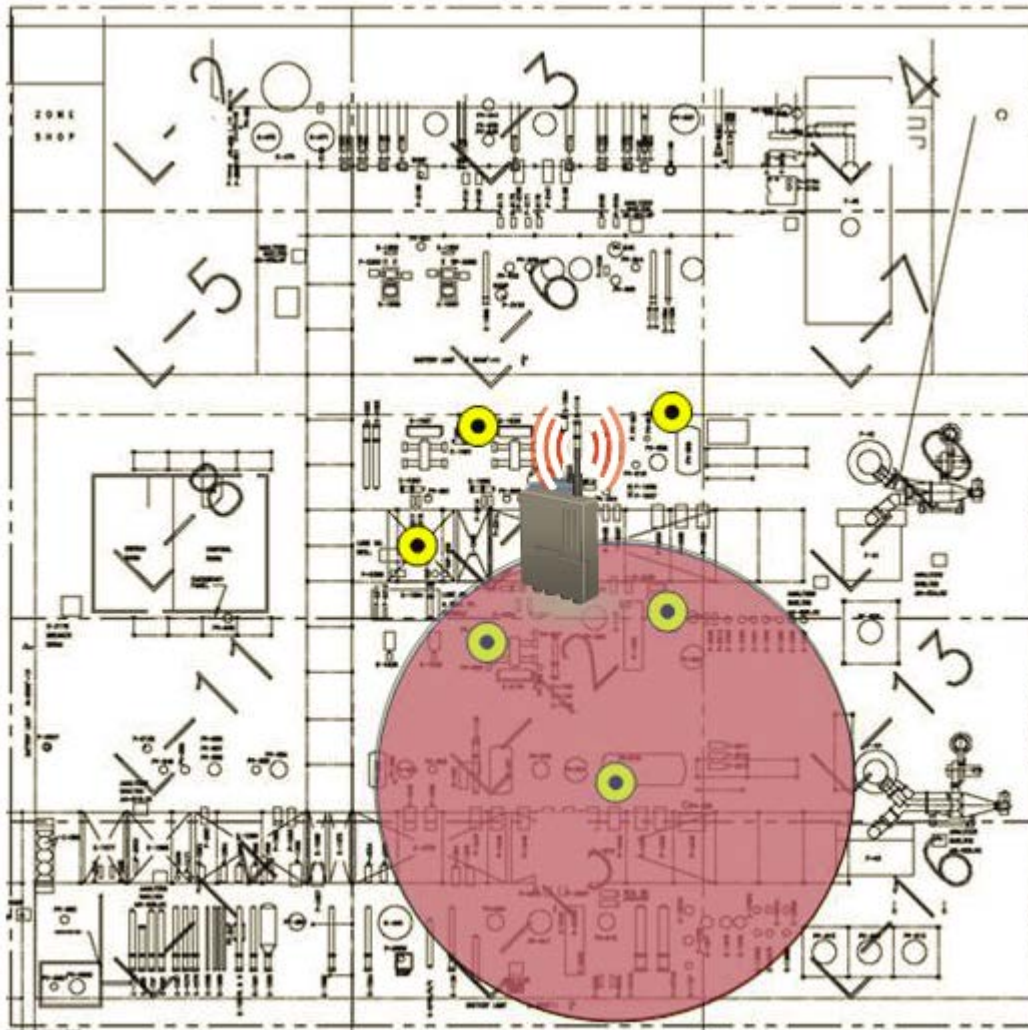


Figure 12. Example Process With Rule of 3 Broken

3. **Rule of Percentages** - Every *WirelessHART* network with greater than 5 devices should have a minimum of 25% of devices within effective range of the gateway to ensure proper bandwidth and eliminate pinch points. *WirelessHART* networks can work with as little as 10%, and actual implementation may yield less than 25%, but experience shows this is a practical number. Example, a 100 device network implies 25 within effective range of the gateway.
 - a. Networks with greater than 20% of wireless devices with update rates faster than 2 seconds should increase the percentage of devices with in effective range of the gateway from 25% to 50%.
4. **Rule of Maximum Distance** – Wireless devices with update rates faster than two seconds should be within 2 times the effective range of wireless devices from the gateway. This rule maximizes speed of response for monitor and control applications requiring high-speed updates.

Applying Network Design Recommendations

WirelessHART devices are located according to their process connection. Only an approximate location is required for location on the scaled drawing since the self-organizing mesh technology will adapt to conditions as they exist and change from the point of installation. The design rules ensure a concentration of *WirelessHART* devices for ample paths between the devices. This allows the self-organizing mesh to optimize networking in a dynamic environment.

When the Rule of 3 is broken, it can be fortified by adding more devices. As networks grow, Rule of 5 minimum and Rule of 3 become irrelevant as there are many devices in the process space. Rule of Percentages becomes dominant for large networks to ensure there is ample bandwidth for all devices in the network. Below is an example of when Rule of Percentages is broken.

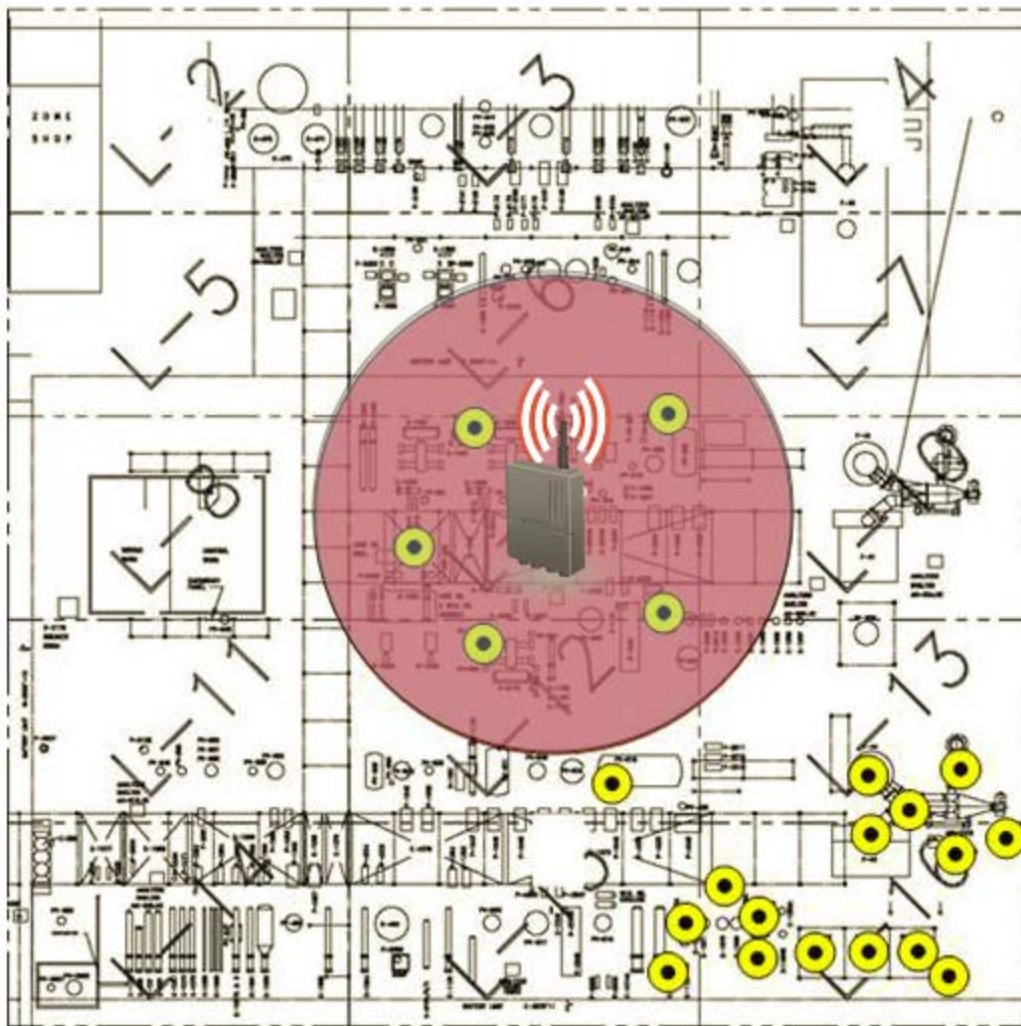


Figure 13. Example Process With Rule of Percentages is Broken

A deviation from the rule of percentages can be resolved in several different ways. Below are three options to fortify this network design, each with its own consideration:

1. Add more devices within the effective range of the gateway. While this is a good solution, there may not be more points of value within effective range of the gateway.
2. Move the gateway into a more central location relative to the distribution of *WirelessHART* instrumentation. In this case, there may not be a convenient host system integration point at the center of the network.
3. Add another gateway. This increases overall capacity for the process unit, addresses the needs of that specific concentration of field devices, and ensures long-term, trouble-free scalability. There may still be the issue with convenient host system integration point as with option 2.

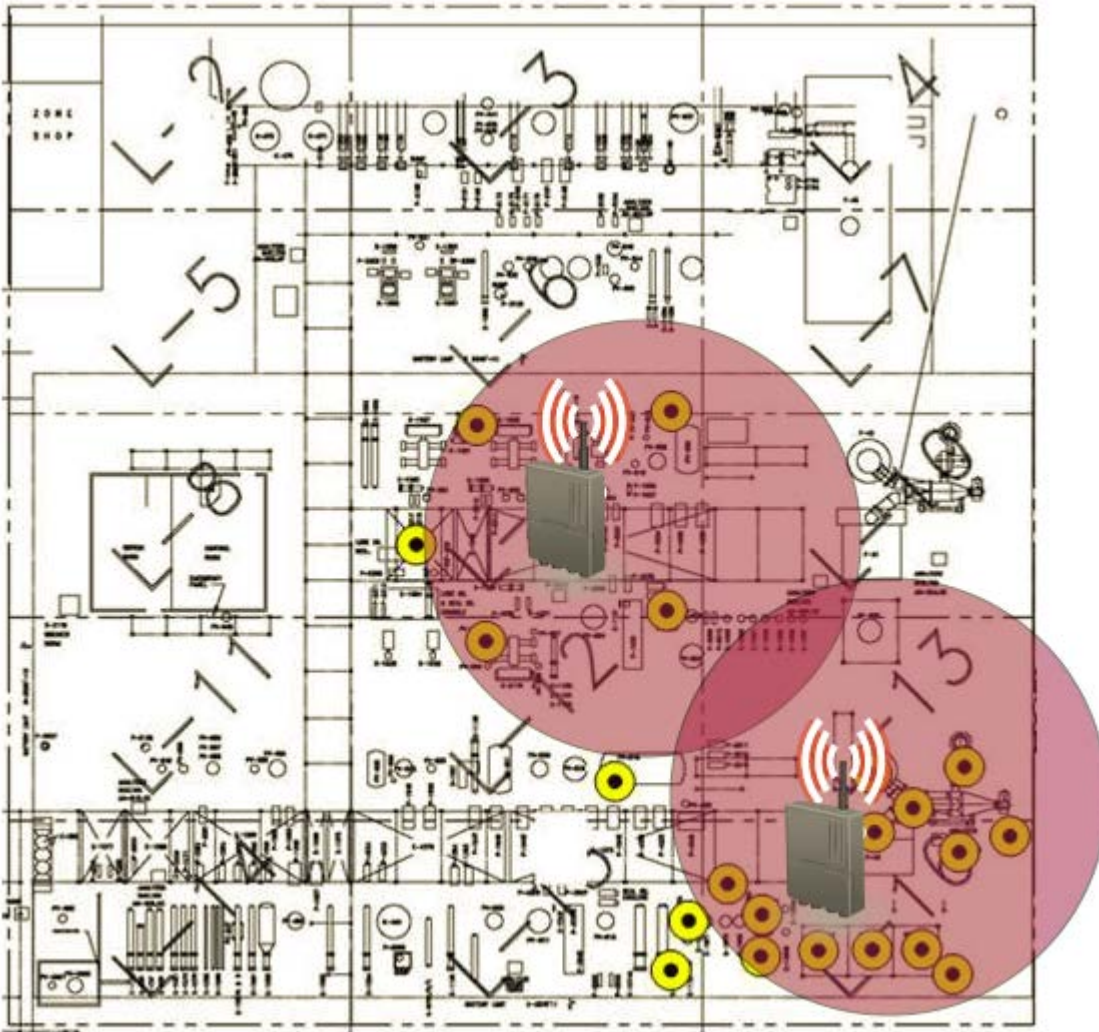


Figure 14. Example Process With Two Gateways

If a wireless device requires update rates faster than 2 seconds or is used for control and does not meet the Rule of Maximum Distance, consider adding a gateway or moving the existing gateway closer to the wireless device. If the process control loop is tolerant of latency, or if it was previously a form of manual control, it may be acceptable to have devices further from the gateway.

Post Installation Considerations for Control and High Speed Networks

Path Stability and Reliability

It is recommended that wireless field devices used for control and high speed monitoring have a higher path stability than general monitoring devices with updates slower than 2 seconds. Path Stability is the measure of successfully transmitted messages on any given path relative to the attempted transmissions. General requirements are 60% path stability, but 70% is recommended for control and high speed monitoring. The additional consideration provided in this text ensures higher path stability that can be confirmed once the network is deployed. Most *WirelessHART* vendors provide the means to verify after installation.

Minimizing Downstream Messages for Wireless Output Control Devices

Digital control signals sent from a host system to a wireless output control device via the gateway require a downstream message. In order to minimize the time for the downstream message to arrive at the wireless control device, downstream messages initiated by non-control applications should be minimized. Maximum downstream message time from gateway to wireless control device is independent of the update rate and should be no more than 30 seconds when network design best practices are followed.

Techniques for limiting miscellaneous downstream messages:

Limit remote configuration of wireless devices when control is in service.

Limit device scans by asset management software.

Limit other actions that require a remote poll and response from the wireless field device.

The update rate of the wireless control device determines how fast the host system receives notification the control command was received and executed.

8.7 Spare Capacity and Expansion

During a typical project there is often a requirement to provide installed spare hardware (marshaling, I/O cards, terminations) and additional spare space. Typically these figures could vary between 20-30%. The consideration when designing with wireless is different as no cabinetry marshaling, I/O cards, and terminations are required. Additional gateways can be added to the network to increase capacity.

8.8 Fortifying

It is recommended to stress test the network design by altering the effective range of devices in order to identify potential weaknesses in the network design. To stress test the network, reduce the effective range of the devices in 10% increments. For example, suppose an effective range of 250 feet (76m) was used for initial design. Reducing effective range by increments of 25 feet (8m) (10%) could reveal where the weak spots will exist. It is the discretion of the network designer to determine what level the network will be stressed; there is a limit of diminishing return.

The example shown in Figure 15 reveals that one *WirelessHART* device fails the Rule of 3 under a 20% stress test of the effective range. Effective range is set to 250 feet (76m) for the design test on the left and 200 feet (61m) for the stress test on the right.

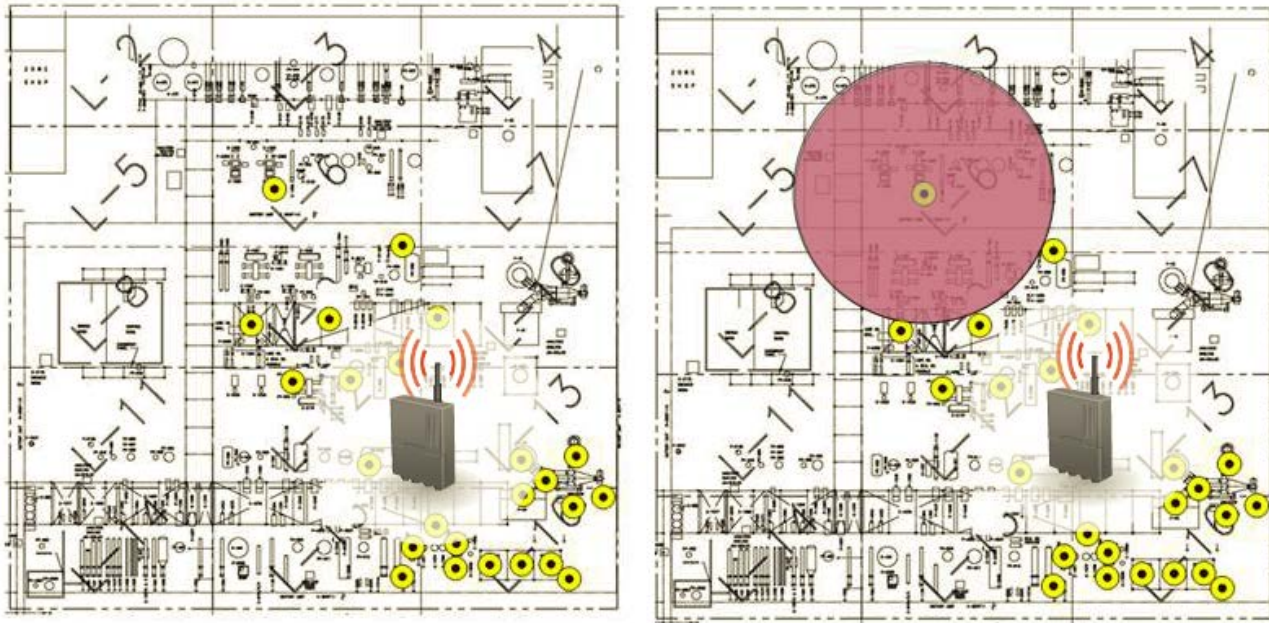


Figure 15. Example Process: Standard Design (Left). Stress-Tested (Right)

The self-organizing mesh technology allows for more *WirelessHART* field devices to be added to a network for the purposes of automation, and provides the means for simple design correction also exist. A stress failure can be fortified by moving the gateway location, adding a new gateway to segment the network, adding more devices or adding repeaters.

Repeaters are an alternative to support the fortification of a network. Instead of another *WirelessHART* device with a specific measurement purpose, any *WirelessHART* device can be used specifically for the purposes of providing more connection within the network. Repeaters can be used effectively within dense infrastructure if they are placed above the infrastructure to maximize the effective range while maintaining connection with wireless devices in the infrastructure. *WirelessHART* adapters may make cost-effective repeaters if local power is available.

8.9 *WirelessHART* Availability and Redundancy

The *WirelessHART* field network is inherently redundant between the wireless field devices and the gateway if the network design recommendations are applied. The user should expect no less than 99% reliability in the flow of data from each *WirelessHART* field device with typical performance approaching 100%.

The following are considerations for maximizing system availability between the host system and the *WirelessHART* Gateway:

1. Always properly ground gateways and field devices per local/national electrical codes and manufacturer recommendations.
2. Always employ proper lightning protection on gateways.
3. Always use an uninterruptible power supply (UPS) to power the gateway. This is the primary source of gateway failure.

4. Deploy redundant gateways for the field network if measurements are critical.
5. Make host systems connections to gateways redundant, especially if redundant gateways are used. This includes physical connections, Ethernet switches and power supplies.

8.10 *WirelessHART* Security

When designing networks, every gateway and thus every network must have a unique Network ID. Wireless device Join Keys may be configured as either common per gateway or individual/unique per field device. If common Device Join Keys are selected as the option, each field device will share the same Device Join Key. If individual Join Keys are selected, each field device in the network will have a unique Join Key.

Individual Join Keys provide stronger security and are recommended. Even with common Join Keys, it is recommended practice to use different values for each gateway and network.

9. HOST SYSTEM REQUIREMENTS

9.1 Use of Standard Protocols

Standard protocols should be used to ensure the most cost effective installation – examples include OPC, Modbus TCP, Modbus RTU, HART IP, etc. The *WirelessHART* gateway should convert data from the *WirelessHART* field network into the desired protocol and physical layer needed for integration into the host system.

9.2 Wireless Host System

Data from *WirelessHART* field networks can be integrated into any existing host system. However many wireless automation applications are not for control or process monitoring and may not be required to be accessed by the DCS or PLC system. This information may be useful to non-control room based personnel including reliability engineers, maintenance personnel, and energy engineers. Careful consideration should be observed for determining which information should be placed on control operations screens to prevent the dilution of critical information.

For example, suppose a wireless field network is used to replace a manual inspection round where a maintenance technician manually collects temperature and vibration data from a series of pumps and then manually enter the collected data into a data historian. Using *WirelessHART*, Figure 16 shows one possible way the gateway can be integrated into the application, in this case a historian, for the automated collection of data.

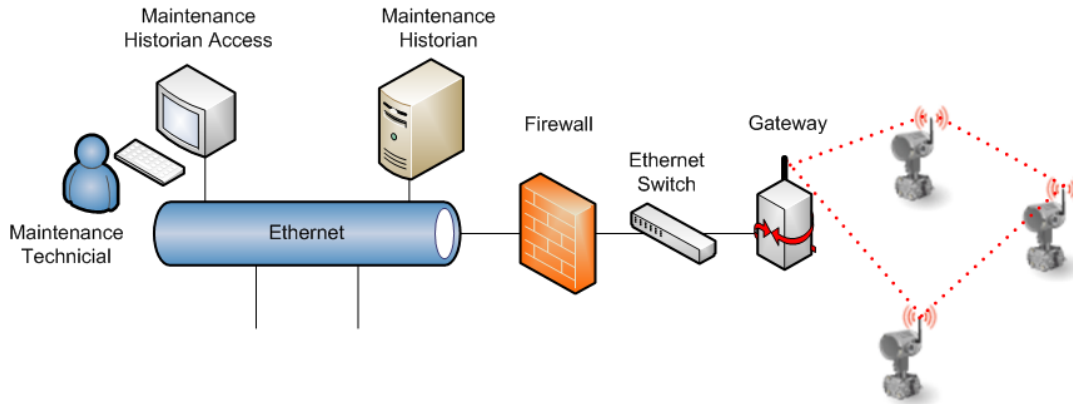


Figure 16. Gateway Integration Into Host System

For *WirelessHART* networks that support users in different roles, the potential exists for each end user to have their own application for collecting and analyzing data. For users who manually collect data, *WirelessHART* provides the missing piece to automation.

For long term scalability, where there may be 1000's to 10,000's of *WirelessHART* devices in a single plant. It is important to have a coordinated effort and standard process to enable end users with different roles and responsibilities to share the I/O capacity of gateways. Representatives from maintenance, utilities, operations, health/safety/environmental, and asset management can share *WirelessHART* network resources.

An architecture to consider is a centralized historian and centralized asset management program shown in Figure 17. In this scenario, multiple gateways are connected on the same Ethernet network and server. The data from multiple *WirelessHART* networks is sent to a centralized historian that can then be connected to the applications for each of the end users. In this way, host system resources can be shared, all *WirelessHART* instruments can report to the same asset management solution, uniform security policies can be enforced, and end users can see *WirelessHART* data in applications specific to their roles.

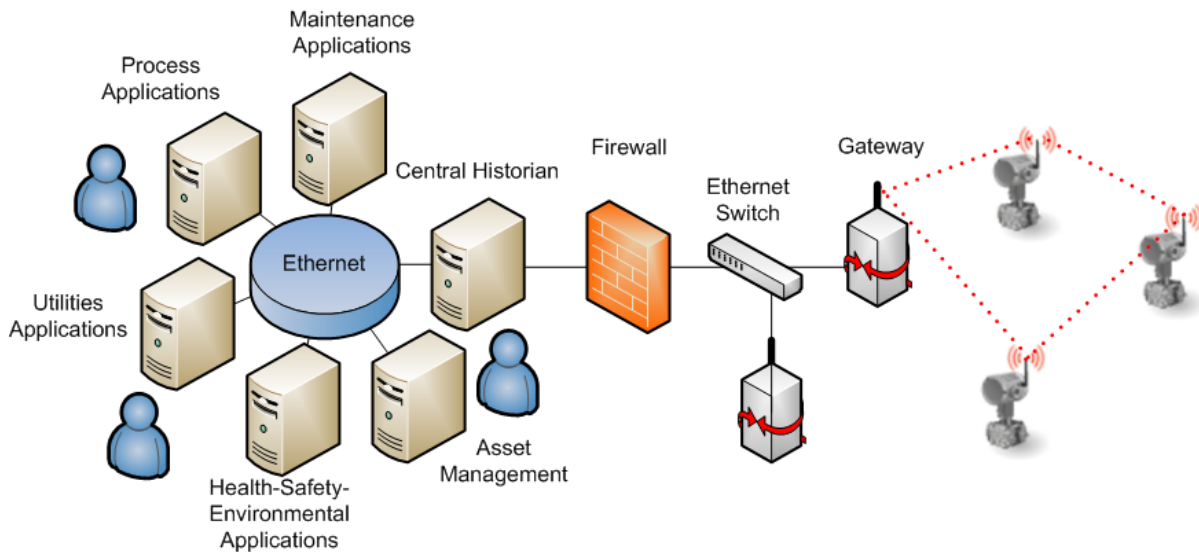


Figure 17. Gateway Information Integrated Into Many Applications

Developing a host system integration and data management strategy is essential to maximizing return on investment for wireless that is adopted on a large scale. Successful implementation means that data is going to the right people and being turned into information for action. Often times, multiple users will see the same data, but in the context of their applications. This also means that every time a new *WirelessHART* device is introduced to the plant, host system and integration issues do not need to be solved again and again.

WirelessHART is truly scalable; *WirelessHART* devices can be added to a network without disrupting operation and more gateways can be added to increase I/O capacity. This ability allows automation to be added and expanded to solve problems without large project budgets once wireless network infrastructure is in place. For example, a *WirelessHART* device can be connected in minutes, configured in minutes, and integrated in minutes if a host system strategy is in place.

9.3 Host Integration

Integration of data originating from the wireless gateway into a host control system is normally performed in one of two ways - through native connectivity directly to the host system or using standard protocols such as Modbus or OPC.

For native connectivity including vendor specific I/O cards, contact the host vendor.

OPC and Modbus are non-proprietary protocols and use standard data exchange and integration techniques to map data from the gateway into the host control system. Typical data that is mapped to the host are process variables (PV, SV, TV, QV), time stamps (if using OPC), and overall device status. Diagnostic information is typically passed to an asset management system via Ethernet. Check with the gateway vendor for compatible asset management packages.

Often, existing host systems can be a combination of legacy DCS and PLC components and modern data management solutions such as data historians. *WirelessHART* gateways should support multiple connections into multiple host systems over multiple protocols. This enables *WirelessHART* networks to support modernization of an existing host system. For example, suppose the existing DCS has no spare capacity and can only receive the 4-20 mA signal from wired HART devices. A *WirelessHART* network could be connected to the DCS to bypass the need for more Analog Input Cards to receive more process variables, while in parallel, HART diagnostics flow to an asset management program from existing wired HART devices with *WirelessHART* adapters. This type of modernization project could enable incremental modernization with an older host system and when the scheduled turnaround occurs to upgrade the DCS, the existing *WirelessHART* networks would transition to the new host system (see Figure 18 for an example transitional architecture).

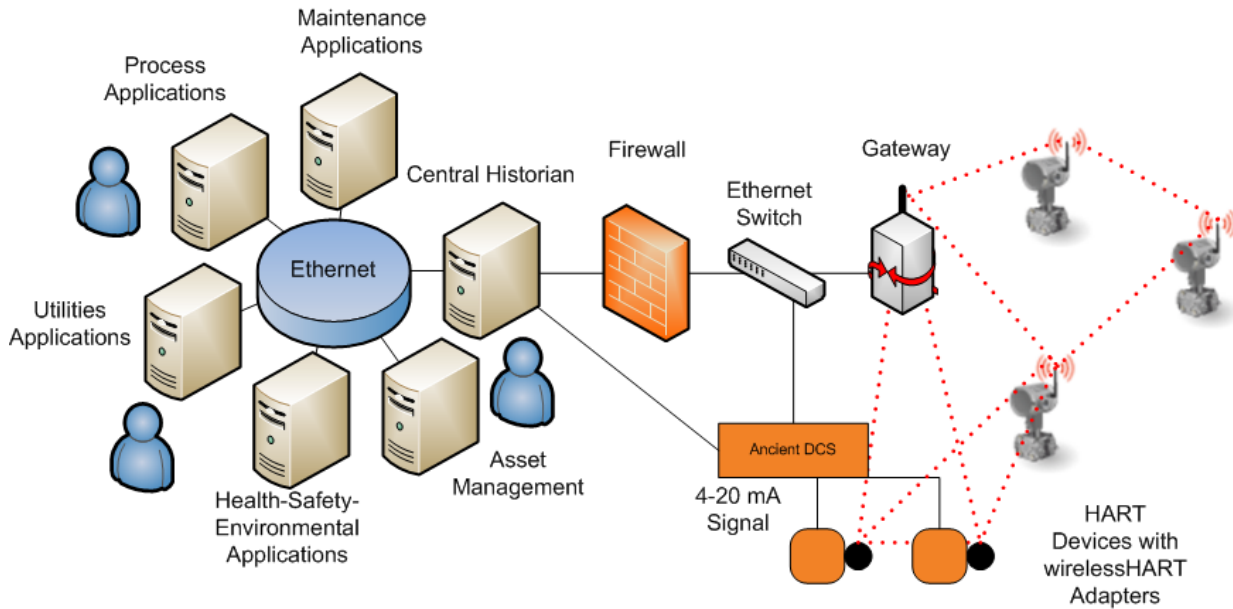


Figure 18. Using *WirelessHART* Gateway To Bridge Information From Non-HART Host System

A key output from working with host system administrators is an integration strategy to incorporate a plant-wide wireless infrastructure. If doing a small application, a key output is the physical locations of where to connect the gateways. These will be needed for the network design process.

Key Outputs for Network Design:

- Identifying a host system administrator and system integrator who supports integration of *WirelessHART* data into the host system.
- Potential physical connection points for *WirelessHART* gateways.

9.4 Interoperability

Converting *WirelessHART* data from the gateway into standard protocols like Modbus and OPC ensures interoperability of all *WirelessHART* networks with all host systems. Host systems based on proprietary protocols will be more difficult to implement, maintain, and expand.

9.5 Host System Support for *WirelessHART* Functionality

A *WirelessHART* gateway typically performs all management of the *WirelessHART* network and manages communications to and from the *WirelessHART* field devices. The host system should not require any special software to support the *WirelessHART* field network.

9.6 Configuration Tools

WirelessHART devices are based on the HART protocol; therefore, existing HART Field Communicators will work for configuration of the field devices. Field Communicators will require the proper device descriptor for configuration, which is the same for any other new HART device, wired or wireless. Host system configuration will be dependent on the host system. HART vendors with asset management software may

extend the benefits of remote management from wired HART to *WirelessHART* devices connected to the gateway.

9.7 Control System Graphics

Not all data collected from the *WirelessHART* field network belongs on the operator screen as part of control system graphics. The risk is that non-pertinent information distracts the operator from critical information.

The host system integration should be configured such that data from a *WirelessHART* field network is delivered to the proper end-user even though network resources are shared. To give some examples:

- Data collected on consumption of power from rotating equipment should go to the utilities manager.
- Data collected on vibration spectrums of rotating equipment should go to asset management.
- Data collected on temperature alarms for rotating equipment should go to operators in a non-obtrusive way and to the reliability manager.

Properly defining an integration strategy will ensure an efficient collection of data from *WirelessHART* network and dissemination to proper end-users. Many end users not typically receptive of the benefits of automation have application specific databases into which data is manually collected and uploaded. With the ability to integrate *WirelessHART* data using standard interface protocols, these existing end-user specific databases can be automatically populated.

9.8 Node Addressing and Naming Conventions

A *WirelessHART* device should follow naming conventions of wired HART devices.

9.9 Alarms and Alerts

Alarms and alerts should be directed to the appropriate end-user and their associated application and software. Alarm and alert dissemination should be reflective of the end user and their responsibility.

9.10 Maintenance Station

WirelessHART devices provide internal diagnostics and process variables like any wired HART device. Additional local diagnostics for network connectivity should be accessible locally via a HART Field Communicator with the correct Device Descriptor for the *WirelessHART* field device.

The *WirelessHART* gateway should also provide additional diagnostics for network performance. The data from *WirelessHART* devices will not propagate to the host system if the data is deemed questionable from either a HART diagnostic or due to an extended delay in reception at the gateway from the *WirelessHART* field device. The gateway can notify the host system if communication problems exist. Additionally, the gateway is responsible for *WirelessHART* network management and network diagnostics.

Diagnostics between the gateway and the host system will depend on the host system and the gateway.

9.11 Historian

Historic Data collection can be treated the same as any conventional source (e.g. OSIsoft PI or any DCS historian package).

10. FACTORY ACCEPTANCE TESTING REQUIREMENTS

10.1 Introduction

The key deliverable of a factory acceptance test (FAT) is the integration of data from *WirelessHART* instruments into the host system via the gateway. The scope of the FAT should be agreed with the end user. Typically only a subset of the field devices and gateways to be installed is used during the FAT.

10.2 Factory Staging

The following are basic requirements for factory staging:

- A sample of all applications, gateways and *WirelessHART* devices is present.
- Approved test plan, test procedure and test acceptance criteria.
- HART Field Communicator and user interface to the *WirelessHART* Gateway.

10.3 Assumptions

Below are assumptions for the FAT:

- Network topology testing is covered as part of the Site Acceptance Test.
- *WirelessHART* network design does not need to be tested at the factory if network design recommendations are implemented. The conservative nature and ability to fortify the network upon installation with repeaters ensures high confidence of reliable operation.

10.4 Factory Acceptance Test (FAT) Requirements

The following are key requirements of a factory acceptance test:

- Physical connection between the gateway and the host system is verified. Can the gateway be accessed from the host system with the proper security policy in place?
- Protocol connection between the gateway and the application that resides on the host system is verified. Can the data seen in the gateway be seen in the application? Can the standard parameters be properly mapped?
- Gateway can support all necessary connections to all required applications with appropriate timing.
- Device Descriptor (DD) for all field devices in any asset management solution is tested. This ensures the correct DD is installed and valid. This is especially important for *WirelessHART* devices that are new to the market.

10.5 FAT Procedure

Since there are no physical IO modules, software testing is performed by simulation of I/O at the processor level. This level of simulation is adequate to verify the application software within the host control system.

As per IEC 62381 standards on factory acceptance testing, general guidance as described for testing of bus interfaces and subsystems shall apply. A subset of instruments (at least one of each type) shall be connected to the gateway as a proof of concept demonstration of integrated system functionality. This test should ideally verify the connectivity of the field device to the gateway and from the gateway to the host systems.

Where physical devices will not be tested at the factory, emulation of the interface will be performed if required.

Below is a high level procedure for performing a FAT:

1. Power the gateway
2. Add one of each type of *WirelessHART* device to the network and verify proper connectivity. All gateway fields for data from the *WirelessHART* device should be properly populated.
3. Create first physical connection to the first required host system application.
4. Verify connectivity between the gateway and the host system application.
5. Integrate necessary data from each sample *WirelessHART* device into the Host System Application.
 - a. Optional additional procedure is to change process variables in the *WirelessHART* device through direct stimulation or through simulation. All devices, once properly connected to the gateway, should integrate identically over protocols like Modbus and OPC.
6. Repeat steps 4-6 while adding host system connections to the gateway until all expected connections the gateway are complete.
7. Test integration into an asset management solution if applicable.
 - a. Verify each *WirelessHART* device can be properly accessed and configured via the asset management solution.
8. Add any additional procedures to verify control narratives and monitoring narratives.

11. SITE INSTALLATION GUIDELINES

Installation practices for *WirelessHART* devices follow very closely the installation practices of wired HART instruments. Since there are no wires, *WirelessHART* devices can be installed as soon as the asset or infrastructure is in place and secure.

11.1 Network Installations

Always install the gateway first so that integration and field network installation and commissioning can occur in parallel.

Field devices can be commissioned into the gateway and then commissioned into the host system application.

In general, *WirelessHART* devices are installed per the practices of wired HART devices. Always consult the product manual.

WirelessHART devices close to the gateway should always be installed and commissioned first to ensure connections for potential devices that cannot directly connect to the gateway. This is the easiest way to establish the self-organizing mesh.

WirelessHART devices can be installed in close proximity to each other without causing interference. The self-organizing mesh scheduling of *WirelessHART* ensures devices in close proximity to each other are silent, talking to each other, or talking on different RF channels when other devices are communicating.

If a *WirelessHART* gateway antenna or *WirelessHART* device antenna is to be mounted near a high power antenna of another wireless source, then the antenna should be mounted at least 3 feet (approximately 1 meter) above or below to minimize potential interference.

11.2 Lightning Protection

The installation manuals of all *WirelessHART* devices should be consulted prior to installation.

In general, *WirelessHART* devices should not be the tallest feature in the plant to maximize protection against lightning.

Ensure adequate protection is provided between the *WirelessHART* gateways and host system connection as a lightning strike could damage more than just the *WirelessHART* gateway. Redundant gateways should never be co-located to provide diversity of location in the event a single *WirelessHART* gateway is struck by lightning.

In general, wireless devices may provide better protection of the system than wired, as the energy from a lightning strike will not be able to travel through the wiring and cause potential damage to other components.

Standards such as NFPA 780 provide classification for zones of protection from lightning as well as techniques for proper implementation.

11.3 Wireless Connection Test Procedure

Before beginning the wireless connection test procedure, verify the *WirelessHART* device has basic connectivity to the network either through the gateway interface, a local user interface on the device, or a local connection via a HART Field Communicator. If the device is not joining the network within a reasonable time period, verify the presence of power and the use of proper Network ID and Join Key. This assumes the gateway is installed properly, powered and accessible, that the network is designed per best practices, and that there are devices to which the new device being commissioned can connect.

1. Wait a minimum of at least 1 hour from initial powering of the *WirelessHART* device before performing the wireless connection test procedure. This dwell time ensures the device has had time to make several connections for self-organization. Multiple devices can be tested at the same time, and since they rely on each other, it is optimal to have as many on the network as possible for initial connection testing.
2. Verify that network diagnostics indicate the device has proper bandwidth. The gateway should have an indication.
3. Verify each device has a minimum of two neighbors. The gateway should have an indication.
4. Verify device reliability is 99% or greater. Statistics may need to be reset and recertified to remove any anomalies incurred during start up and not indicative of long term performance. Allow at least 1 hour for the network to gather new network statistics.
5. Verify sensor configuration per the loop sheet or other form indicating designed configuration.
6. Perform any necessary zero trims for sensors.
7. Repeat for each device in the network.

If a device does not pass the wireless connection test, then follow these basic steps:

1. Wait until entire network is built and operating for 24 hours before considering further action. This will give the gateway time to maximize its self-organization for best communication. If 24 hours is too long to wait, allow a minimum of 4 hours.
2. For the non-compliant device, verify proper path stability and RSSI values. Path stabilities should be greater than 60% and RSSI should be greater than -75 dBm. Wireless control devices and devices with update rates faster than 2 seconds should have a path stability of 70% or greater. If all the devices on the network have very low path stabilities, but high values for RSSI, this could be an indication of broadband interference.
3. Look at the location of the non-compliant device in the network. Verify there is not a broken network design rule or an unexpected installation resulting in poor RF signal propagation.
 - a. Add repeaters if necessary to fortify the network if the device is isolated from the network with poor connections.
4. Verify the device has proper power and is working properly as a sensor.
5. Verify the device update rate is not faster than the fastest allowed by the gateway.
 - a. Either reduce the update rate of the field device or increase the fastest allowed update rate on the gateway.

11.4 Network Checkout Procedure

Below are basic steps for checking out a network. Allow a minimum of 4 hours for the network to self-organize (24 hours is preferred):

1. Verify that all devices connected pass the wireless connectivity test. The gateway should have an indication.
2. Verify a minimum of 15% of devices are directly connected to the gateway. The design parameter is 25%; the minimum acceptable is 10%. Networks with more than 20% of devices with update rates faster than 2 seconds or wireless control devices have a design parameter of 50% and 40% should be connected after installation. The gateway should have an indication.
3. Verify overall network reliability is greater than 99%. The gateway should have an indication.

11.5 Loop Checkout/Site Integration Tests

Once *WirelessHART* devices are connected to the gateway and the network is checked out, the loop checkout may not be necessary in the traditional sense.

Wireless connection testing verifies each field device has the proper configuration. Since there are no wires to get confused and swapped, there is no need to do the traditional loop check. Alternative loop checks could be to ensure each field device is reporting to the correct gateway and each gateway is connected into the correct host system. Traditional applications of sensor stimulus can be performed for confidence, but are less valuable in a pure digital architecture if there is complete assurance a field device was commissioned with the correct tag and configuration.

11.6 Bench Simulation Testing

Each *WirelessHART* field device is compliant with the IEC 62591 protocol which has provisions for simulation. Each device can be put into a simulation mode. Bench simulation testing should also verify that all HART Field Communicators have the proper configuration and device descriptors (DDs) for accessing the local user interface of field device when in the field.

11.7 Provision of Spares

Below are the recommended spares to have onsite:

- Spare lightning arrestor components for gateways, if lightning protection is used.
- Spare gateways should be kept according to spares policy for host system equipment (e.g. I/O cards). Configurations for gateways should be convenient for rapid replacement if necessary.
- Spare battery modules
- Spare field devices as determined by the policy for wired field devices. Consideration should be given for additional devices to be used as repeaters if necessary.

11.8 Removal of Redundant Equipment

Repeaters used temporarily to fortify a network can be removed and reused if the *WirelessHART* network grows to a point where repeaters are no longer needed.

11.9 Maintenance Practices

Maintain each *WirelessHART* device per the manual for the device.

The network will self organize and provide alerts for changes requiring intervention. The gateway should have an indication of performance issues in the network or field devices.

12. DOCUMENTING IN INTERGRAPH SPI 2009

WirelessHART devices can be fully documented in Intergraph SPI with minimal customization. Below is an example of how to document *WirelessHART* in a logical, linear order and assumes the reader is skilled in working with Intergraph SPI. This is just an example to illustrate the methodology. Ultimately it is the responsibility of project management to create and reinforce the application of standards and guidelines within the project environment.

12.1 User Defined Fields

The first step is to create user defined fields that allow for the accounting of *WirelessHART* engineering parameters that are necessary for defining if a point is wireless and how that point will be connected to a network.

The following global User Defined Fields should be created:

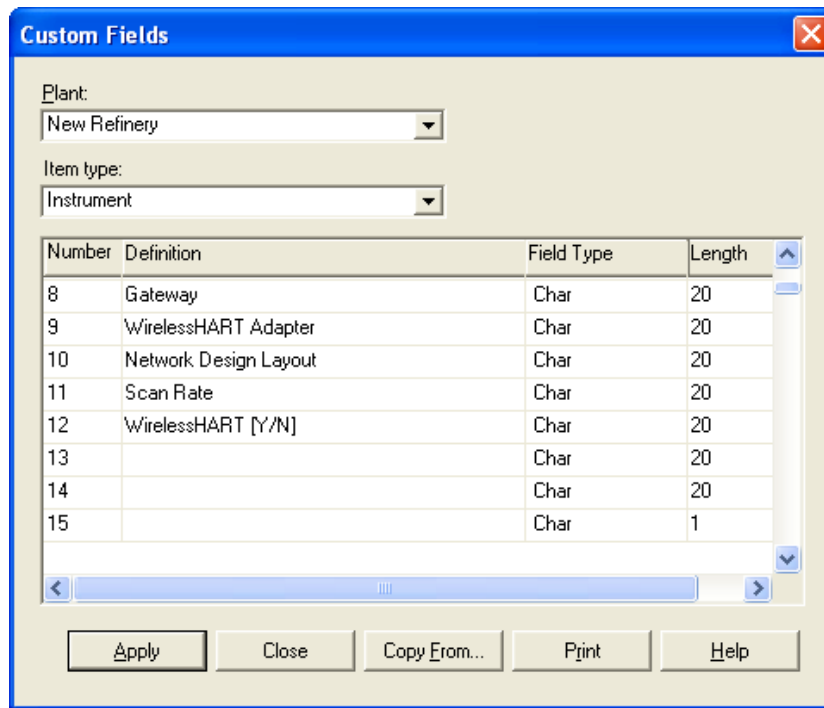


Figure 19. SPI User Defined Fields (UDF) For *WirelessHART*

Explanation of fields:

User Defined Field (UDF)	Field Type	Example	Purpose
<i>WirelessHART</i> (Y/N)	Char	Y	Identify a point as wireless at a high level. Will be used for quickly applying design guidelines to determine what is and what is not wireless.
Update rate	Char	1,2, 4, 8, 16,32,64+	<i>WirelessHART</i> devices will not all scan at 1 second like wired HART devices. This value will be important for determining what devices may be <i>WirelessHART</i> as well as setting configuration parameters.
Gateway	Char	GWY002	Defines which gateway a <i>WirelessHART</i> device is to be associated.
<i>WirelessHART</i> adapter	Char	WHA001	Defines which <i>WirelessHART</i> adapter a wired HART device is associated with if a device does not have integrated <i>WirelessHART</i> capability.
Network Design Layout	Char	A101.DWG	This is a reference field to a drawing or document that was used to validate network design best practices.

Figure 20. Definitions for *WirelessHART* SPI User Defined Fields

Field Type refers to the type of value that can be entered for the value of the UDF. In the case of all the *WirelessHART* parameters, these are all just CHAR (or characters, also meaning text). Likewise, the Length refers to the max length that can be entered into the field.

If the user chooses, SPI rules can be created such that these custom fields only appear for points that are HART or checked to be *WirelessHART*. This minimizes exposure to non-pertinent information for non-*WirelessHART* devices.

12.2 Filtered Views

A custom view of the Instrument Index will be useful for applying design guidelines for selecting what instruments are to be wireless as well as seeing the organization of networks. Below is a sample view leveraging the User Defined Fields shown in the previous section.

Tag Number	Service	IO Type Name	Loop Name	Criticality	Scan Rate	WirelessHART [Y/N]	Gateway	WirelessHART Adapter	Network Design Layout
101-FY -300		HART AO	101-F -300	Normal		N			
101-FV -300/A	Feedback number 1	HART AI	101-F -300	Normal		N			
101-FT -300		HART AI	101-F -300	Normal		N			
101-PI -300/A	Fluid Pressure	HART AI	101-F -300			N			
101-FI -300/B	Mass Flow	HART AI	101-F -300			N			
101-TI -300/A	Fluid temperature	HART AI	101-F -300			N			
101-FT -346		HART AI	101-F -346	Low	30 SEC	Y	GWY002		AREA_A_321_LYT
FT346FV		HART AI	101-F -346	Low	30 SEC	Y	GWY002		AREA_A_321_LYT
FT346PV		HART AI	101-F -346	Low	30 SEC	Y	GWY002		AREA_A_321_LYT
101-FT -401		HART AI	101-F -401						
PV1	Vibration Motor-001	HART AI	101-S -001						
101-ST -001	Vibration Motor-001	HART AI	101-S -001						
ST_100_PV	Vibration Motor-001	HART AI	101-S -001						
ST_100_SV	Vibration Motor-001	HART AI	101-S -001						
101-ST -001 /I	Vibration Motor-001	HART AI	101-S -001						
101-SX -001	Vibration Motor-001	HART AO	101-S -001						

Figure 21. Custom View Of SPI’s *WirelessHART* User Defined Fields

The “Criticality” and “Update rate” should be foundations for any engineering guidelines that determine whether a device is *WirelessHART*. Some low criticality loops may have update rates faster than 4 seconds, and should be included with the design guidelines. Because *WirelessHART* devices primarily run on batteries, *WirelessHART* may not be suited for all fast update rate applications.

At a high level, using the “Criticality” and “Update Rate”, engineers can determine whether a device should be *WirelessHART*. If wireless, the device will need to be associated with a gateway. If a device can only be specified as a wired HART device and requires a *WirelessHART* adapter, then the “*WirelessHART* Adapter” tag information should be defined.

Every *WirelessHART* field network should be validated against network design best practices. “Network Design Layout” provides a reference field to link to the drawing on which network design best practices were checked.

12.3 Creating Instrument Types

Early in the process, symbols and instrument types should be defined and a *WirelessHART* instrument library should be developed. Below the basic modifications to a HART device to create a *WirelessHART* instrument type is illustrated.

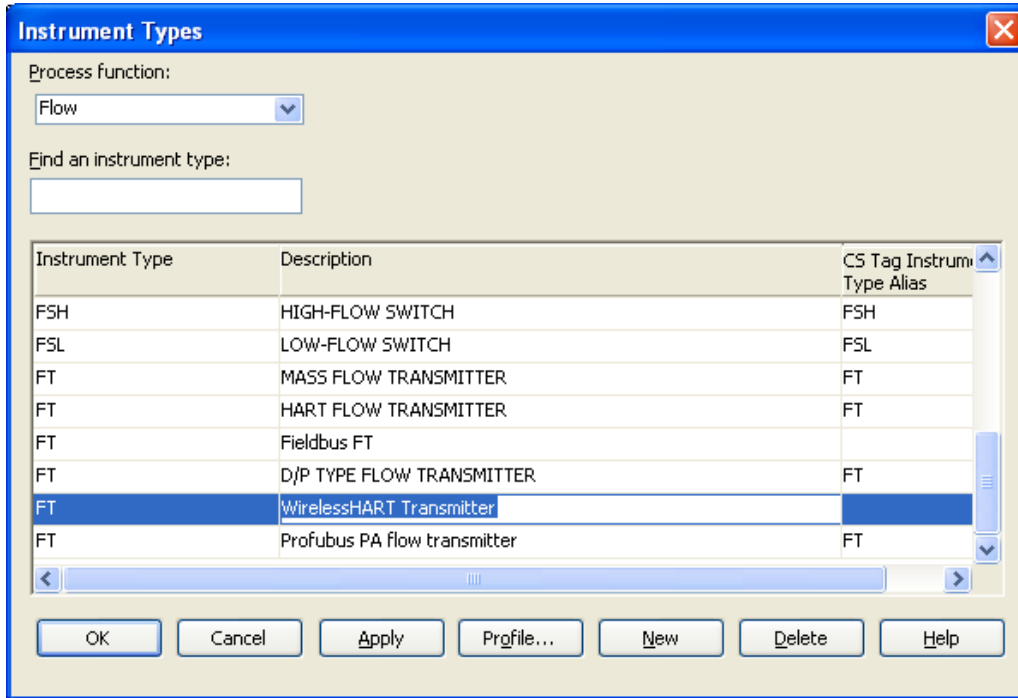


Figure 22. Defining *WirelessHART* Instrument Type In SPI

The first step is to create a new device with a new description. In this example, we have created a *WirelessHART* flow transmitter. Please note that if the device will be specified as a wired HART device with a *WirelessHART* adapter, no new instrument types are necessary.

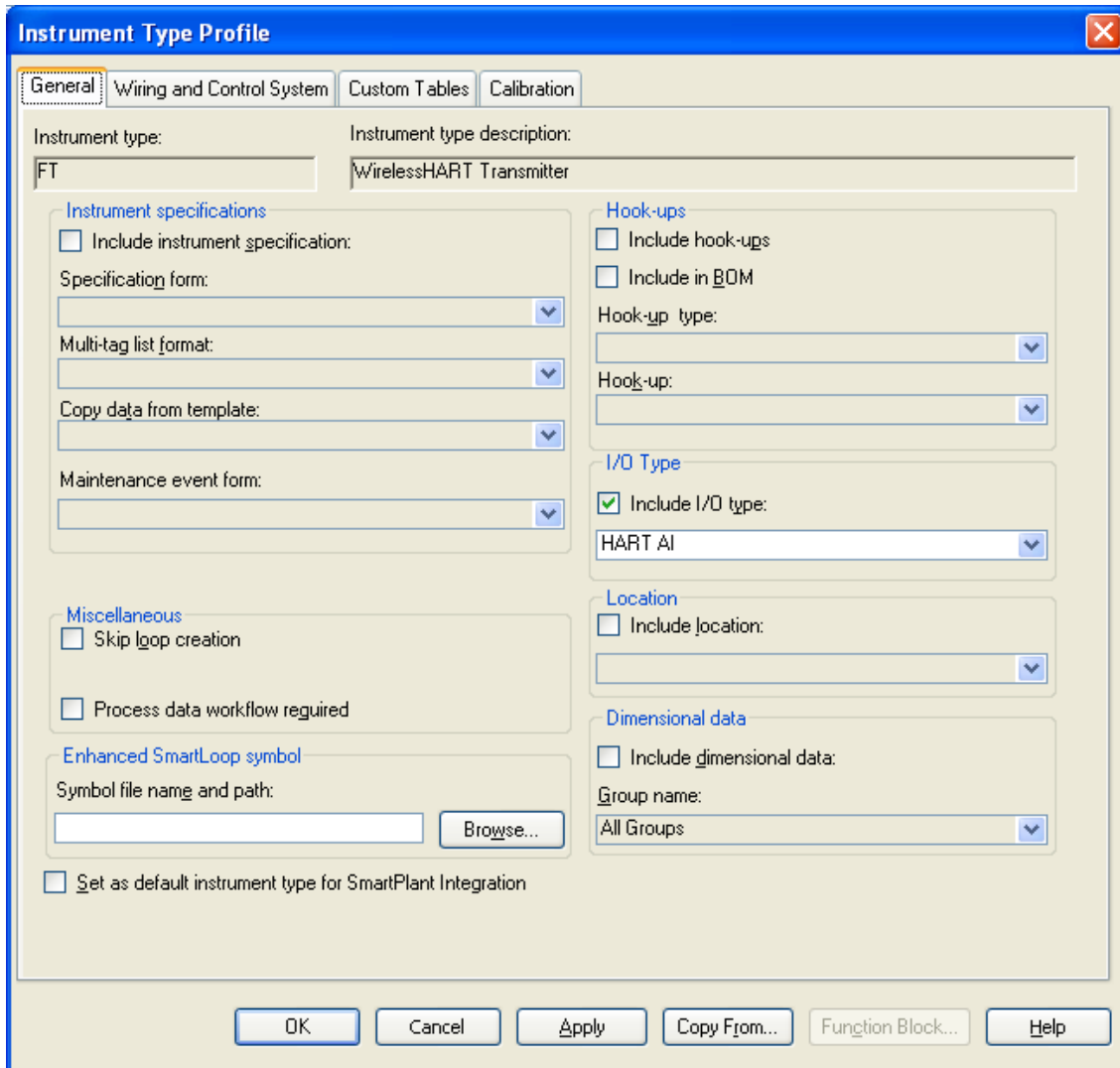


Figure 23. Defining A New *WirelessHART* Instrument In SPI

Nothing needs to change on the general tab. Be sure to leverage that the device is a HART AI or a HART AO so that all of the basic parameters of HART apply. Manage the wiring, or lack of wiring separately. The fact that *WirelessHART* is based on HART allows leverage these pre-defined variables.

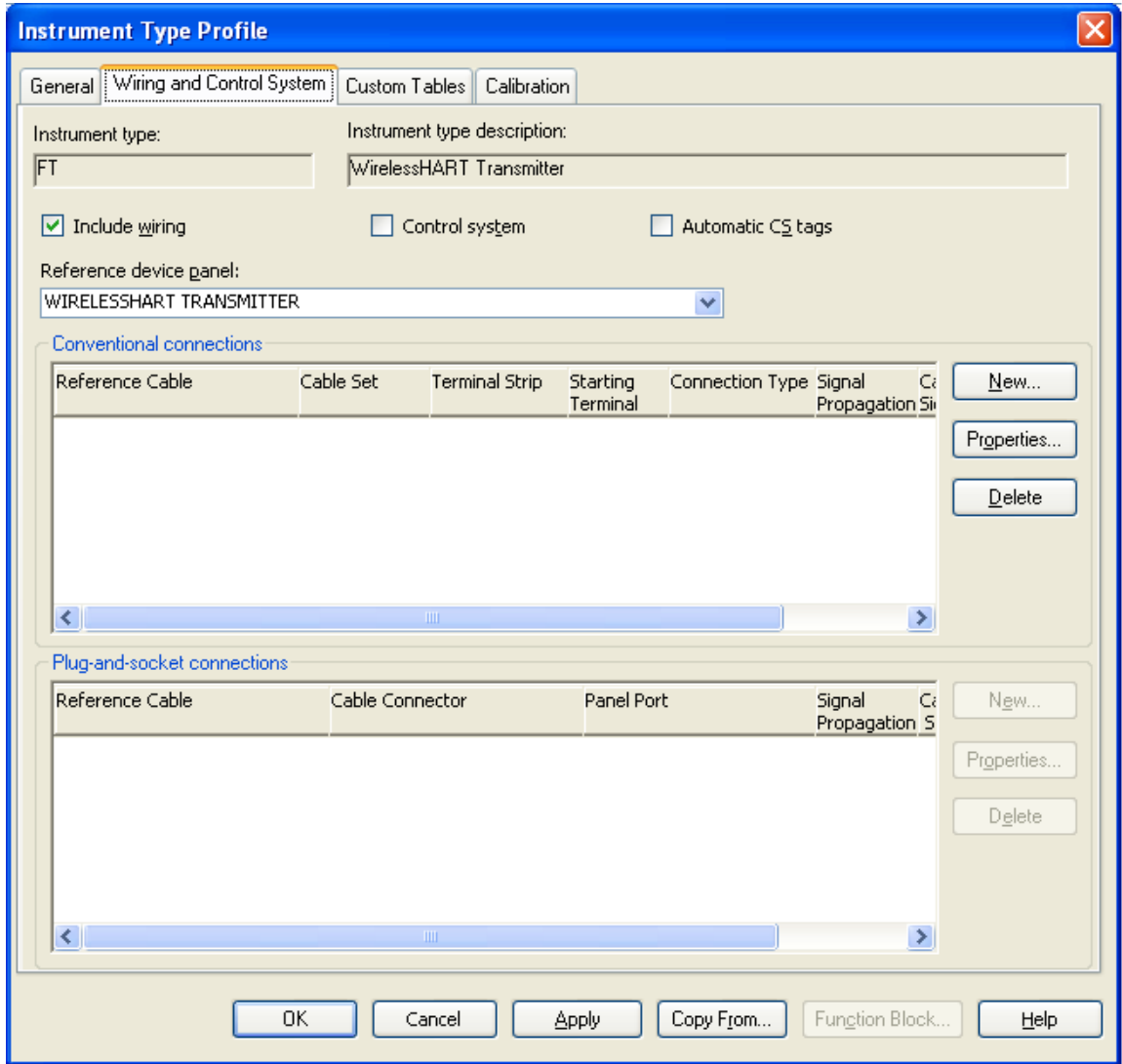


Figure 24. Defining Wiring Types In SPI

Check the box to include the wiring. If this box is not checked when SPI generates loop drawings, the device cannot be added to loop drawings. This also allows for flexibility for different wiring configurations, to be defined elsewhere. Examples include wiring *WirelessHART* adapters in series with the loop and line power for *WirelessHART* devices. This process should be repeated for each unique *WirelessHART* instrument type.

There are only two instrument types that are unique to *WirelessHART* and could be considered ancillary - the *WirelessHART* gateway and the *WirelessHART* adapter. To create these instrument types, it is recommended to use the symbols YG for a *WirelessHART* gateway and YO for a *WirelessHART* adapter.

Once the instrument type is defined, the device panel properties can be modified to include reference symbols. It is recommended to assign symbols for both the Enhanced SmartLoop and the Cable Block Drawing.

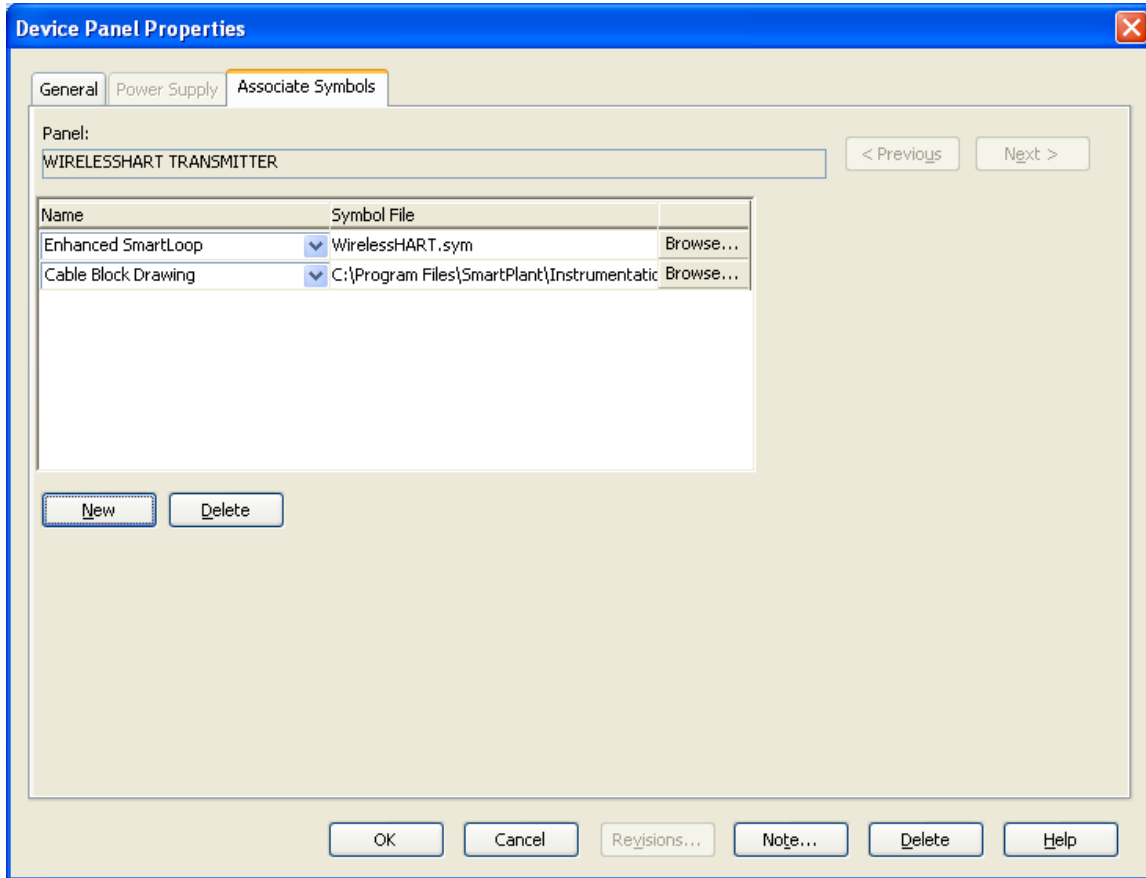
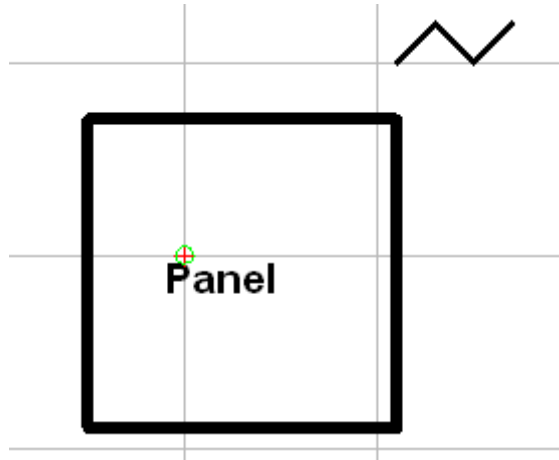


Figure 25. Assigning Symbols In SPI

Basic symbols can be created in SPI using the editing tools. Below are examples for *WirelessHART* field devices and a *WirelessHART* gateway. The zig-zig symbol shown below is defined by ISA. For more documentation, nothing special is required since signaling is typically not well indicated. For auto-generated documents, it may be useful to include the update rate by referencing the User Defined Field, although this is not an absolute requirement. Most importantly, the project management team decides on a symbol convention and remains consistent throughout the project.

WirelessHART Gateway symbol:



WirelessHART Device Symbol:

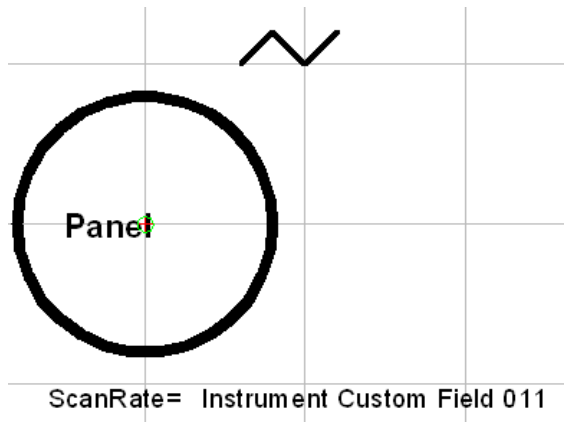


Figure 26. *WirelessHART* Symbols

WirelessHART devices can be connected to a *WirelessHART* gateway using the User Defined Field. This type of drawing does not show the path through the *WirelessHART* network, but does show the relationship of the *WirelessHART* device and the *WirelessHART* gateway: Below is an example from the ISA-5.1 document, page 118.

B.9.5 Shared display, shared control and wireless instrumentation:

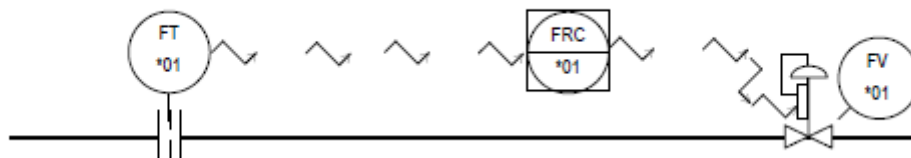


Figure 27. ISA 5.1 Drawing Example

Please note that inclusion of update rates and the wireless signal symbol are optional. The authors of this document found the practice of including such information supportive of adopting and managing the unique attributes of *WirelessHART*.

12.4 Loop Drawings

Given that *WirelessHART* field devices do not require signal cabling, the documentation of the equivalent of wireless loop drawing is very simple to create.

The key information is to relate each wireless field device to the respective gateway. It is recommended that a basic wireless loop drawing show the traditional tag information as well as the *WirelessHART* User Defined Fields. This way, it is very clear to see which wireless devices are associated to which *WirelessHART* gateway. Currently, Intergraph SPI 2009 does not have the means to implement this in a specific drawing, thus it is recommended to use the Instrumentation Index showing the *WirelessHART* User Defined Fields. In the image below, a comprehensive list of *WirelessHART* devices are shown associated to different gateways.

Tag Number	Service	I/O Type Name	Loop Name	Criticality	Scan Rate	WirelessHART [Y/N]	Gateway	WirelessHART Adapter	Network Design Layout
FT346FV		HART AI	101-F -346	Low	30 SEC	Y	GWY002		
FT346PV		HART AI	101-F -346	Low	30 SEC	Y	GWY002		
101-FT -346		HART AI	101-F -346	Low	30 SEC	Y	GWY002		AREA_A_321_LV
101-ST -001	Vibration Motor-001	HART AI	101-S -001				GWY003		
101-SX -001	Vibration Motor-001	HART AO	101-S -001				GWY003		
101-TI -300/A	Fluid temperature	HART AI	101-F -300			N			
101-FI -300/B	Mass Flow	HART AI	101-F -300			N			
101-PI- 300/A	Fluid Pressure	HART AI	101-F -300			N			
101-FT -300		HART AI	101-F -300	Normal		N			
101-FY -300		HART AO	101-F -300	Normal		N			
101-FV -300/A	Feedback number 1	HART AI	101-F -300	Normal		N			
FT348_PV		HART AI	101-F -348						
101-YO -348		HART AI	101-F -348						
101-FT -348		HART AI	101-F -348						
101-FT -401		HART AI	101-F -401						
ST_100_PV	Vibration Motor-001	HART AI	101-S -001						
ST_100_SV	Vibration Motor-001	HART AI	101-S -001						
101-ST -001 #1	Vibration Motor-001	HART AI	101-S -001						
PV1	Vibration Motor-001	HART AI	101-S -001						

Figure 28. Filtered View Of *WirelessHART* Tags

This list can then be filtered and printed by gateway. A key piece of information is the link to a drawing verifying that best practices have been verified which can also include physical instrument location.

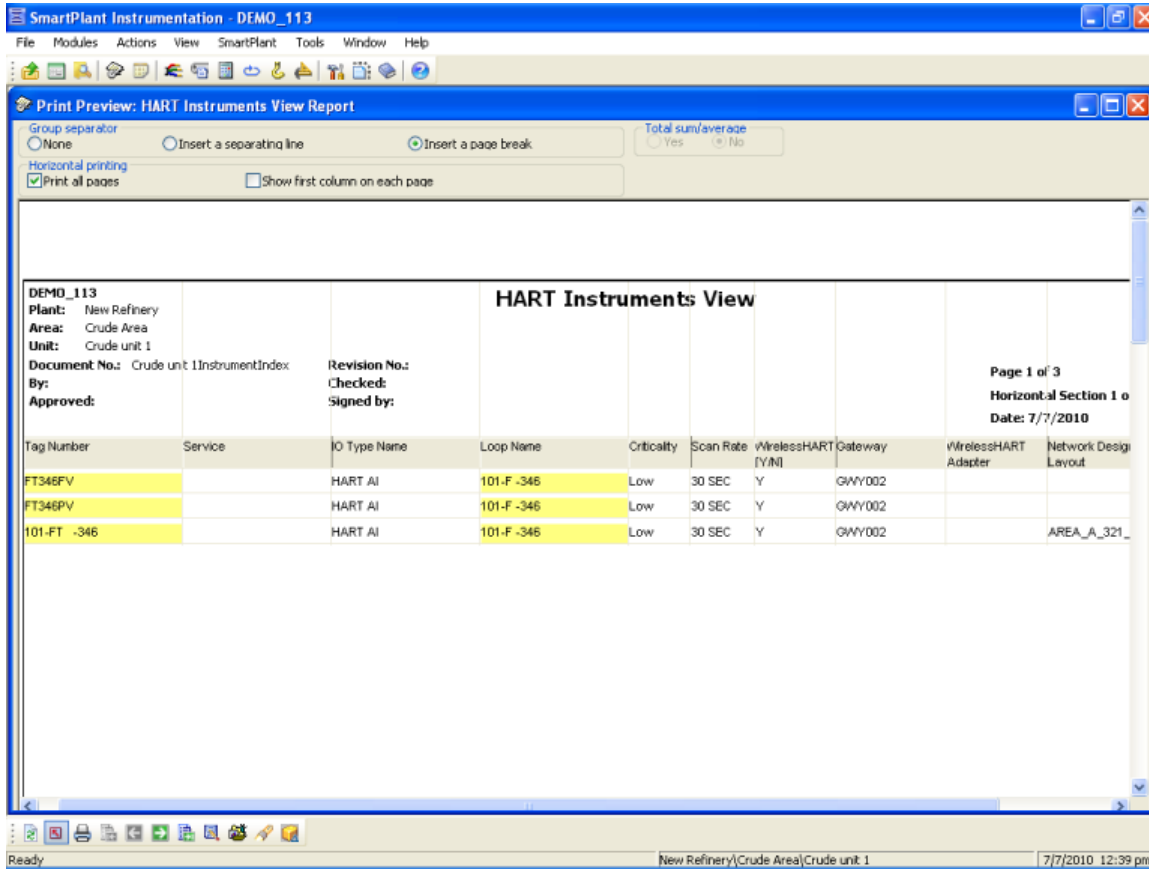


Figure 29. Tag View Filtered By Gateway

Loop Drawings for *WirelessHART* Adapters

A *WirelessHART* adapter is an accessory to a loop and should be treated as a loop accessory like a multiplexor or transient protection. Loop accessories are traditionally not indicated on the loop drawing and are installed on site. It is recommended for simplicity that there are no modifications for the loop drawing of a wired HART device to reflect the presence of a *WirelessHART* adapter.

The *WirelessHART* adapter would be properly documented and accounted for on the Wireless Loop Drawing that shows the gateway and all associated *WirelessHART* devices.

Gateway Cable Block Drawings

A useful drawing to create is a Gateway Cable Block Drawing showing the gateway power and communication connections. All *WirelessHART* gateways, regardless of vendor, should have uninterruptible power supplies to maximize system reliability.

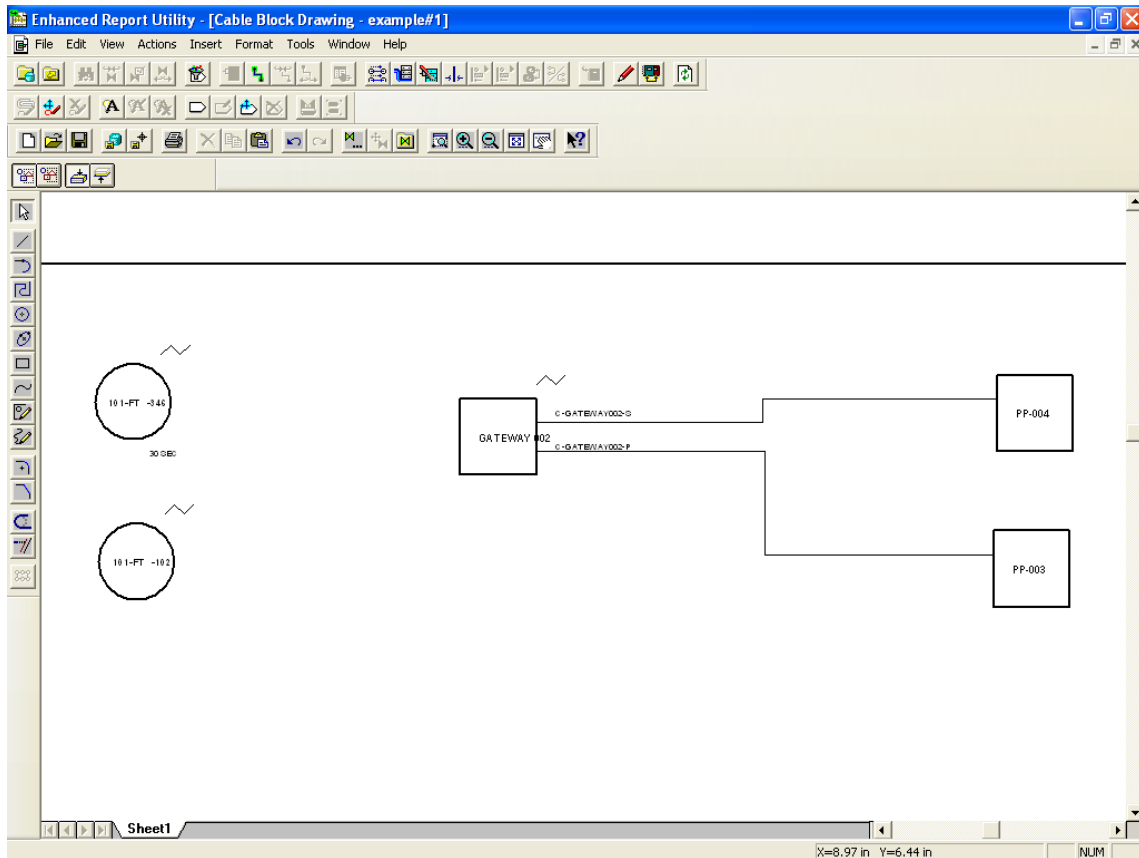


Figure 30. Gateway Cable Block Diagram

An additional drawing to consider, possible with a Cable Block Diagram, would be to show all gateways assigned to an area on the same document for convenience.

12.5 SPI Specification Sheets

Existing specification sheets can be used to indicate *WirelessHART* devices. Key fields to change are listed in the table below:

Specification Field	Typical Value
Update rate	4, 8, 16, 32, 64+
Power Supply	Intrinsically safe, field replaceable battery
Communication Type	<i>WirelessHART</i>

Since *WirelessHART* is derived from wired HART, other specification fields should be completed as if it is a wired HART device.

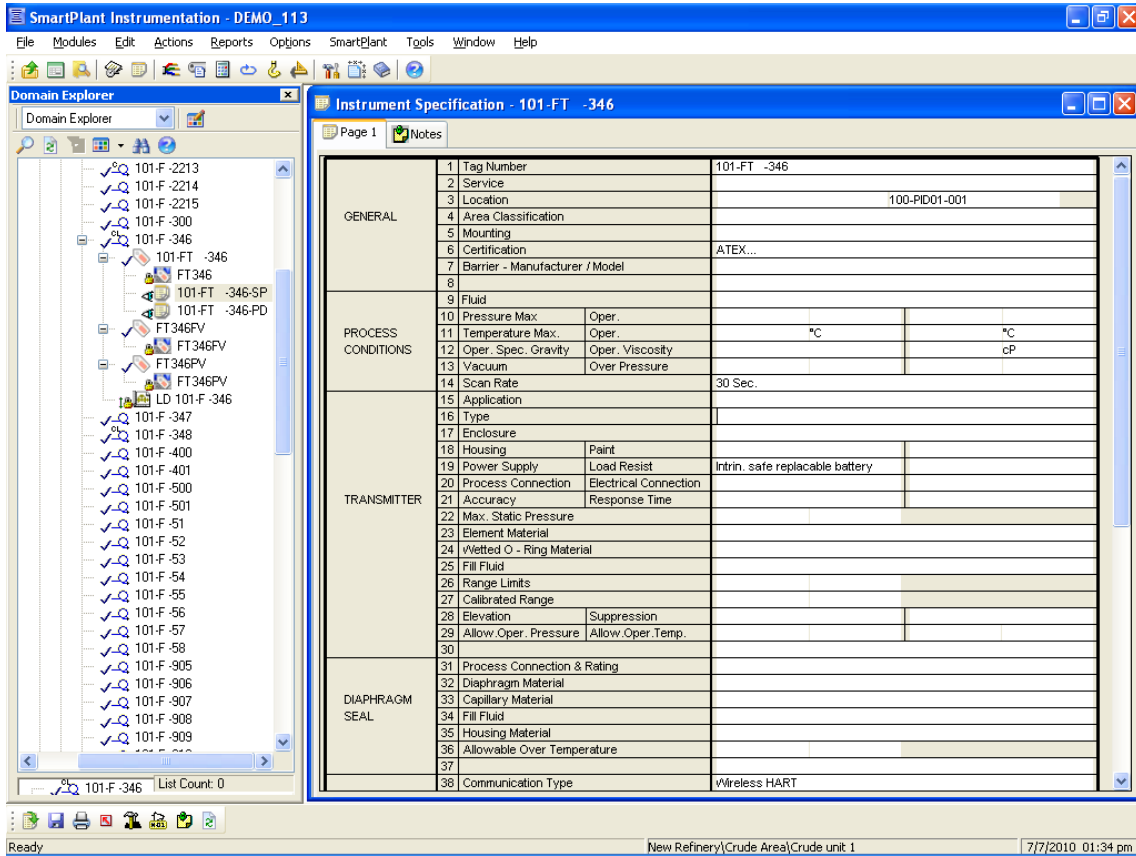


Figure 31. *WirelessHART* Instrument Specification Sheet

12.6 Drawings in SPL – Smart Plant Layout

WirelessHART devices should be installed as their wired HART counterparts. Therefore, all *WirelessHART* devices can be indicated in drawings without deviation from the practices used for wired HART devices.

WirelessHART gateways should be located like per the network design guidelines.

12.7 Documenting Security Information

The *WirelessHART* security parameters of Network ID and Device Join Key(s) should not be a part of a wireless loop drawing or in the SPI design environment. These are security parameters used to protect the network and should be managed per a local security policy implemented by the Owner/Operator. The Network ID and Device Join Key(s) are not required for the design. The wireless loop drawing associates the *WirelessHART* device with the *WirelessHART* gateway tags. Separately, secure documents containing *WirelessHART* security provisioning including the *WirelessHART* gateway tag can be used to cross reference the Network ID and Join Key(s). Remember, all Network IDs and common Device Join Keys (if used) should be unique for every gateway and every *WirelessHART* field network. This type of security management is similar to the management of security information for control systems and servers

ANNEX A. Example ISA Specifications

Below is a sample specification for a *WirelessHART* gateway.

		RECEIVER INSTRUMENTS (Wireless Gateway)				SHEET _____ OF _____	
		NO	BY	DATE	REVISION	SPEC. NO.	REV.
						CONTRACT	DATE
						REQ.	P.O.
						BY	CHK'D
							APPR.
1	Tag No.	Service					
2	Function	Record <input type="checkbox"/> Indicate <input type="checkbox"/> Control <input type="checkbox"/> Blind <input type="checkbox"/> Integ <input type="checkbox"/> Deviation <input type="checkbox"/> Other IEC 62591 wirelessHART Network Administration/Setup					
3	Case	MFR STD <input checked="" type="checkbox"/> Nom Size 229mmX283mm Color: MFR STD <input checked="" type="checkbox"/> Other Blue					
4	Mounting	Flush <input type="checkbox"/> Surface <input type="checkbox"/> Rack <input type="checkbox"/> Multi-Case <input type="checkbox"/> Other Field mounted with or without remote antenna					
5	Enclosure Class	For Multiple Case, See Spec. Sheet General Purpose <input type="checkbox"/> Weather Proof <input checked="" type="checkbox"/> Explosion-Proof <input type="checkbox"/> Class Class I Div II For Use in Intrinsically Safe System, <input type="checkbox"/> Other IEC 62591 wirelessHART field Network					
6	Power Supply	117 V 60Hz <input type="checkbox"/> Other ac _____ dc <input checked="" type="checkbox"/> 24 Volts					
7	Chart	Strip <input type="checkbox"/> Roll <input type="checkbox"/> Fold <input type="checkbox"/> Circular _____ Time Marks _____ Range _____ Power _____ Number _____					
8	Chart Drive	Speed _____					
9	Scales	Type _____ Range 1 _____ 2 _____ 3 _____ 4 _____					
10	Control Modes	P = Prop (Gain), I = Integral (Auto Reset), D = Derivative (Rate), Sub: s = Slow, f = Fast P <input type="checkbox"/> PI <input type="checkbox"/> PD <input type="checkbox"/> PID <input type="checkbox"/> I _s <input type="checkbox"/> D _f <input type="checkbox"/> I _s <input type="checkbox"/> D _s <input type="checkbox"/> Other _____					
11	Action	On Meas. Increase Output: Increases <input checked="" type="checkbox"/> Decreases <input type="checkbox"/>					
12	Auto-Man Switch	None <input type="checkbox"/> MFR STD <input type="checkbox"/> Other _____					
13	Set Point Adj.	Manual <input type="checkbox"/> External <input type="checkbox"/> Remote <input type="checkbox"/> Other _____					
14	Manual Reg	None <input checked="" type="checkbox"/> MFR STD <input type="checkbox"/> Other _____					
15	Output	4-20 mA <input type="checkbox"/> 10-50 mA <input type="checkbox"/> 21-103 kPa (3-15 psig) <input checked="" type="checkbox"/> Other OPC, Modbus RTU, Modbus TCP, HART, HIRL					
16	Input Signals	4-20 mA <input type="checkbox"/> 10-50 mA <input type="checkbox"/> 21-103 kPa (3-15 psig) <input type="checkbox"/> Other IEC 62591 wirelessHART					
17	No. of Inputs	1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> X 100 devices					
18	Power for XMTRS	External <input checked="" type="checkbox"/> This Inst <input type="checkbox"/> No. of Independent Supplies _____ For Transmitters. See Spec Sheet.					
19	Alarm Switches	Quantity _____ Form _____ Rating _____					
20	Function	Meas. Var. <input type="checkbox"/> Deviation <input type="checkbox"/> Contacts To _____ On Meas _____ Other _____					
21	Options	Filter-Reg <input type="checkbox"/> Supply Gage <input type="checkbox"/> Charts <input type="checkbox"/> Int. Illumination <input type="checkbox"/> Other Multiple Ethernet connections, remote mount antenna, additional output protocols, additional hazardous area approvals					
22	MFR & Model No.	_____					
Notes:							
1. Support device burst (scan) rates from 4 seconds to 60 minutes.							

Figure 32. ISA Sample Wireless Gateway Specification Sheet

ANNEX B. Wireless Spectrum Governance

Wireless applications have been deployed in the process industry for over 40 years. In any process facility, applications using RF signals including personnel communications, RF ID systems, ad hoc systems, and cell phones exist. The essential ingredients to making wireless automation feasible were solving the problems of power to enable devices to operate on batteries for multiple years; self-mitigating RF obstacles in the process environment so expert wireless knowledge was not a requirement for adoption; and coexisting with other RF sources.

WirelessHART operates in the 2.4 GHz Industrial, Scientific, and Medical (ISM) radio band that typically operates from 2.400-2.480 GHz. The exact frequency limitations and RF output power levels may be slightly different country by country. *WirelessHART* employs limitations that allow for universal operation in almost all countries with exceptions being noted for specific products by device manufactures. The ISM radio bands are license-free, but do require approval from governmental regulating agencies. These approvals are typically obtained by the *WirelessHART* vendor. Since vendors for multiple applications can use the same spectrum, *WirelessHART* must be able to successfully coexist.

WirelessHART uses multiple techniques to coexist with other wireless applications:

- Network segmentation – allows thousands of *WirelessHART* devices to exist in the same physical space, provided each network has a unique Network ID.
- Spectrum isolation – wireless applications in different portions of the RF spectrum do not “see” each other and thus do not interfere with each other.
- Low power – *WirelessHART* devices are very low power relative to handheld personnel communicators, Wi-Fi, and RFID readers. This helps prevent *WirelessHART* interference with these high power applications.
- Spatial hopping – self-organizing mesh networks can hop on different paths that may be exposed to different RF conditions. The *WirelessHART* devices self-organize paths through the process environment that mitigate RF obstacles the same way as physical obstacles.
- Channel hopping – *WirelessHART* devices use 15 channels within the 2.4 GHz spectrum. Pseudo-random channel usage ensures that interference on one or several channels does not prevent reliable communications.
- DSSS coding – allows transmissions to be modulated with unique encoding for the purposes of jamming resistance, channel sharing, and improved signal/noise level. DSSS Coding extends radio receiver sensitivity through digital processing.
- Time Synchronized Mesh Protocol (TSMP) – provides the synchronized time slots which schedule coordinated network communication, only when required in order to preserve battery life and reduce interference.
- Despite these coexistence features, it is still beneficial to have some form of wireless governance. *WirelessHART* can be interfered with, but only under severe conditions that likely will disrupt all wireless applications operating in the 2.4 GHz spectrum such as Wi-Fi and Bluetooth.

A key example is broadband interference. Many legacy wireless systems are very high power. As an example, consider a personnel communication system using high power two-way radios operating in the 800 MHz frequency range. Although the system is legal and operating according to specifications, it can emit broadband interference that spans several GHz in the spectrum. This broadband interference then affects all applications in other RF bands by reducing the signal-to-noise ratio. The simple solution is to place a band pass filter on all systems such that they only emit RF energy in the spectrum licensed for usage. See the illustrative diagram below showing broadband interference before and after the implementation of a low pass filter.

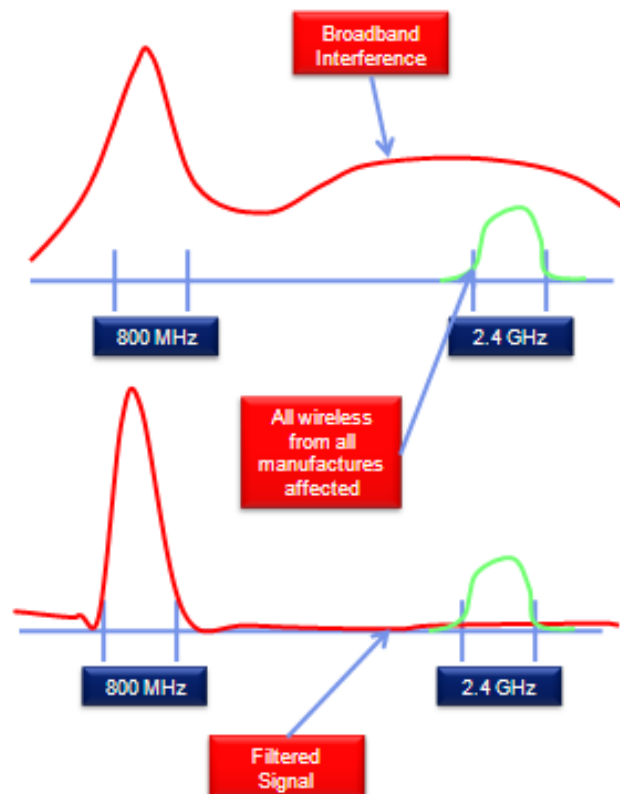


Figure 33. Installing A Low-Pass Filter

Most government agencies make the licensing of high power radios public information since there is the potential to interfere with private and public entities other than the licensee. In the United States, the federal government makes all licensed radios searchable at <http://wireless2.fcc.gov/UlsApp/UlsSearch/searchLicense.jsp>. If a facility has licensed radios, efforts should be made to verify low-pass filters are in place on high powered system in all RF bands. The regulations were created before the advent of low-power systems, including Wi-Fi, and future consideration was not given to coexistence of low power with high power systems. Other countries are also likely have a similar type of searchable database.

Installing passive low pass filters is straight forward and typically only requires insertion of the filter in series with existing RF cabling and proper resealing of RF connections. All existing wireless will benefit by the installation including Wi-Fi.

The emerging 802.11N Wi-Fi standard may emit broadband interference if operating a non-802.11N application in the 2.4 GHz ISM radio band. Relative to 802.11B or 802.11 G which use a single Wi-Fi channel (typically 1, 6, or 11 in North America), 802.11N will use multiple adjacent channels to enable increased bandwidth for demanding applications such as bulk data transfer, security cameras, and streaming video. 802.11N can be operated in either the 2.4GHz ISM band or the 5.8 GHz ISM band. Operation in the 5.8 GHz band applies the principle of spectrum isolation and comes with the additional advantage that 5.8 GHz RF signals can transfer information much faster than 2.4 GHz RF signals due to the much faster modulation.

Another emerging standard is Wi-Max, which operates in the 2.3 GHz, 2.5 GHz, or 3.5 GHz radio bands. Although these spectrums do not overlap the 2.4 GHz spectrum, there are no provisions in the Wi-Max standard to adopt or enforce the usage of low-pass filters in either clients or Access Points. The high power of Wi-Max has the potential to interfere with all wireless applications specifically designed for operation in the 2.4 GHz spectrum. Wi-Max clients should have limited deployment in or near the process facility. Installing passive low-pass filters on each segment of a Wi-Max antenna will further mitigate potential interference problems.

Aside from managing potential broadband interference sources, wireless governance a basic process. Below is a summary of key considerations for wireless governance:

- A local wireless governance policy should serve the purpose of documenting all wireless sources in a plant and enforcing best practices for wireless coexistence.
- Enforce proper installation and compliance with regulation for all wireless applications with regards to power levels, spectrum usage, and encryption in accordance with government regulation.
- Provide guidelines for wireless applications spectrum usage.
 - Limit 802.11N Applications to 5.8 GHz ISM radio band.
 - Use low-pass filters on all high-power RF systems.
 - Put high bandwidth wireless applications such as security cameras in the 5.8 GHz radio band.
 - Ensure all RF coaxial cables are properly installed with weather sealant tape or comparable method to mitigate reduction in performance due to exposure to the environmental elements.
- Support proper segmentation of *WirelessHART* networks.
 - Every network in the process facility should have a unique Network ID and Join Keys.
 - *WirelessHart* networks can overlap in the same physical space without causing interference problems with each other. Gateway antennas should be installed at least 1 meter apart.

ANNEX C. References

Topic	Reference
WirelessHART	<p>HART Communication Foundation http://www.hartcomm.org/protocol/wihart/wireless_technology.html - Protocol Specifications, Overview, Member Companies.</p> <p>WirelessHART: Real-Time Mesh Network for Industrial Automation http://www.amazon.com/gp/product/1441960465?ie=UTF8&tag=easydeltavcom-20&linkCode=as2&camp=1789&creative=9325&creativeASIN=1441960465, Comprehensive resource on <i>WirelessHART</i>.</p>
Security	<p>ANSI/ISA-TR99.00.01-2007 – “Security Technologies for Industrial Automation and Control Systems” (ISA Technical Report provides an “assessment of various cyber security tools, mitigation counter-measures, and technologies...” as of the publish date) http://www.isa.org/Template.cfm?Section=Standards2&template=/Ecommerce/ProductDisplay.cfm&ProductID=9665</p> <p>DHS – Main Control Systems Security Program (CSSP) website: http://www.us-cert.gov/control_systems (An actively supported government resource for Industrial Control System security information, many links to other resources)</p> <p>DHS – Recommended Practice for Patch Management of Control Systems http://www.us-cert.gov/control_systems/practices/documents/PatchManagementRecommendedPractice_Final.pdf (an example of the Recommended Practices documents available)</p> <p>DOE – “21 Steps to Improve Cyber Security of SCADA Networks” (an oldie but a goodie) http://www.oe.netl.doe.gov/docs/prepare/21stepsbluelet.pdf</p> <p>Emerson – “DeltaV System Cyber-Security” http://www2.emersonprocess.com/siteadmincenter/PM%20DeltaV%20Documents/Whitepapers/WP_DeltaVSystemSecurity.pdf</p> <p>NISCC/BCIT – “Firewall Deployment for SCADA and Process Control Networks” (from 2005, but still a great reference) http://www.oe.energy.gov/DocumentsandMedia/Firewall_Deployment.pdf</p> <p>CPNI – “Deployment Guidance for Intrusion Detection Systems” (lots of good stuff from UK’s Centre for the Protection of National Infrastructure) http://www.cpni.gov.uk/Documents/Publications/2003/2003011_TN1003_Intrusion_detection_deployment.pdf</p> <p>NIST – SP 800-53, Revision 3 “Recommended Security Controls for Federal Information Systems and Organizations” (this latest version includes Appendix I:</p>

Industrial Control Systems, Security Controls, Enhancements, and Supplemental Guidance) <http://csrc.nist.gov/publications/nistpubs/800-53-Rev3/sp800-53-rev3-final.pdf>

NSA – “Defense in Depth” (excellent whitepaper on this important security concept) <http://www.nsa.gov/ia/files/support/defenseindepth.pdf>

NSA – “The 60 Minute Network Security Guide (First Steps Towards a Secure Network Environment)” (The NSA’s Information Assurance website has a lot of useful information) <http://www.nsa.gov/ia/files/support/I33-011R-2006.pdf>

SANS – “20 Critical Security Controls – Version 2.0, Twenty Critical Controls for Effective Cyber Defense: Consensus Audit Guidelines” (note link to printer friendly version) <http://www.sans.org/cag/>

ANNEX D. Revision History

A. 1. Revision 1.0

Initial Revision