System Engineering Guidelines

IEC 62591 *Wireless*HART®

(May - 2014 Revision 04)

PREFACE

Emerson Process Management has developed the **"System Engineering Guidelines"** for *Wireless*HART to support the requirements of *Wireless*HART end users adopting self-organizing mesh networks within the process industry. This document is intended to provide complete technical guidance for using *Wireless*HART devices and applications.

Vital information is captured in the document for the user to make full use of the system application. The information is presented in a 'generic' fashion and does not incorporate any 'value added' features available from any specific vendor.

This document is divided into two Parts for better understanding of the engineering guidelines. The PART I addresses the application of *Wireless*HART technology in different project execution stages starting from the appraise (conceptual design) to the operation phase.

PART II explains the various terminologies of *Wireless*HART, that are used during the various stages of project execution.

The guidelines documented herein include a description of the system functions and capabilities, contingencies and alternate modes of operation, and step-by-step procedures for system access and use. This document assumes the reader is proficient with HART instrumentation; and therefore it focuses on the unique aspects of deploying *Wireless*HART systems. Unless stated otherwise, the reader should assume the project steps are the same for HART and *Wireless*HART instrumentation.

This technical guidelines document summarizes the essential pre-requisites and general guidelines necessary for smooth execution of the project that contains *Wireless*HART Technology. The guidelines provided herein are applicable for small and large scale projects.

The technical guidelines may only be used and operated-on by qualified personnel capable of observing the safety instructions from device manuals. This document is for informational purpose and is provided on an "as is" basis only. The document may be subject to future revisions without notice. The authors and contributors will not be responsible for any loss or damage arising out of or resulting from a defect, error or omission in this document or from any personnel's use or reliance on this document.

We want to hear from you

Your comments and suggestions will help us to improve the quality of system engineering guidelines. If you have any suggestions for improvements, comments, recommendations or a query, please feel free to drop your feedback to a Wireless Specialist:

WSEGSupport@Emerson.com

Definitions and Acronyms

The following definitions are used within this document.

Ancillary device

Any device that does not contain 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 marshalling panels and junction boxes. The gateway functionality may also exist in native *Wireless*HART I/O cards with field radios.

Host System

Any system accepting data produced by the *Wireless*HART 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

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 *Wireless*HART radio and software or an existing installed HART-enabled field device with an attached *Wireless*HART 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.

Acronyms

The following acronyms are used within this document.

Abbreviation	Description
AMS	Asset Management System
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
HART	Highway Addressable Remote Transducer
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 Defined Fields
WFN	*Wireless*HART Field Network

Contents

PART I

*Wireless*HART Project Execution

1 Introduction

*Wireless*HART is a global IEC-approved standard (IEC 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. *Wireless*HART field networks (WFN) communicate data back to host systems securely and reliably and can be applied to both control and monitoring applications.

The similarities between *Wireless*HART 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 FEED (Front-End Engineering and Design) of new projects. Additionally, by removing the physical constraints of wiring and power (as well as reduced weight and space). Wireless networks provide new flexibility in project execution providing solutions which can mitigate risk and improving project schedules.

1.1 Purpose

The purpose of this IEC 62591 *Wireless*HART System Engineering Guidelines is to demonstrate the applicability of *Wireless*HART devices in Projects of any size.

1.2 Scope

This document includes considerations for *Wireless*HART Technology and devices through the complete project cycle as well as subsequently during plant operations.

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

1.3 *Wireless*HART in Project Execution Lifecycle

Figure 1 illustrates a typical framework for project execution and will be used as a basis for describing application of WirelessHART by each phase of the project . Although WirelessHART can be introduced at any phase of a project a strategic benefit is realised by its introduction during the early part of the project execution cycle.

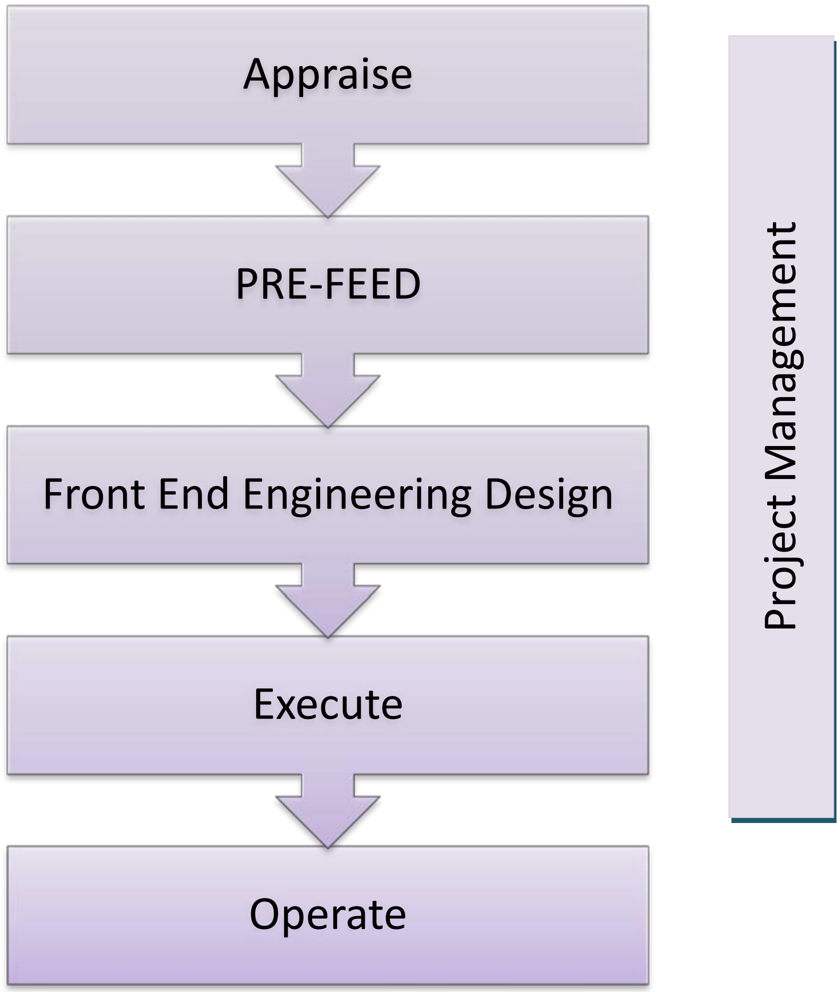


Figure 1: *Wireless*HART in Project Execution Lifecycle

2 Project Concepts

This topic explains the benefit of today's technology over traditional project architectures. WirelessHART technology integrated in a conventional project can be used as risk reduction tool during execution whilst providing greater flexibility and a significant benefit to the plant asset during its life cycle.

2.1 Traditional Approach

Traditional methods of wired control networks make use of conventional communications like 4-20 mA, HART, Foundation Fieldbus, Profibus and other bussed solutions. Significant efforts are essential in the pre-FEED and FEED phases for planning long run cables whilst managing spares considerations associated with the infrastructure in the anticipation of any potential change which may occur on the project.This is an established process with limited scope for innovation to radically change the way design engineers and project managers approach a project.

In addition, measurement of parameters in locations inaccessible to cable trays and therefore wired connection, are always an area of concern and sometimes such measurements are eliminated from the design process as being to costly to implement during the CAPEX phase of a project.

Spare considerations during the initial execution phase, if incorrect, can cause a major impact due to modifications at a later stage. In a typical project environment, frequent changes in I/O database, addition/deletion or reallocation of instruments, change in instrument types, delayed or late changes in package vendor data etc negatively impact project time and cost.

During the maintenance phase, if instruments and therefore I/O points need to be added/changed/moved, then lengthy procedures need to be followed for wired signals such as HSE, work permits, correct isolation procedures, and requisite cabling to connect the field instrument to the control system. These activities require coordination between multiple plant departments. Furthermore, routine inspection to ensure that the cable and associated infrastructure continue to operate trouble free, can be costly and time consuming and divert valuable resources away from operating the plant.

2.2 Technology Assesment

Today's *Wireless*HART technology provides an opportunity to execute and build a more efficient plant compared to the traditional approach.

The Project technical authority will make a decision to use wireless based on the following 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 *Wireless*HART does not require wires for communication or power, the financial impediment in determining whether 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. *Wireless*HART 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 *Wireless*HART 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. *Wireless*HART provides a unified infrastructure for extending the benefits of automation to multiple plant initiatives without the need for multiple forms of I/O infrastructure.

Mitigation strategies of traditional risk models' lack innovation. *Wireless*HART provides greater flexibility and an advantage of minimum engineering efforts, in addition to greater savings in cost and time during any project phase, as compared to the traditional approach.

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

3 Appraise

Appraise phase (conceptual design) requires high level customer requirements or project constraints as input. In this phase a simple statement of requirements with identified constraints or objective will suffice. Selection of Wireless technology in this phase allows a simple generic philosophy statement to be made on how the architecture can be utilised to meet the needs of both the business and the project.

Following Figure 2 shows the inputs and outputs of the Appraise phase...

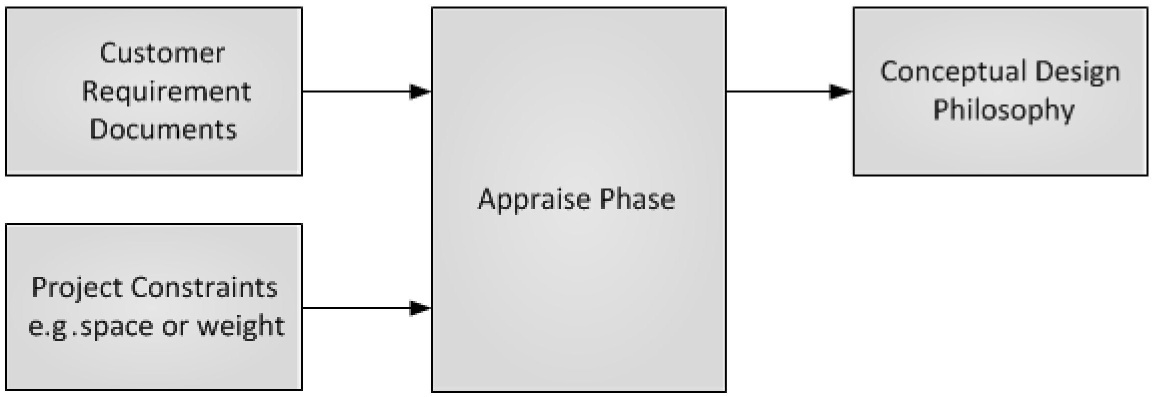


Figure 2: Conceptual Design Phase

During the Appraise phase it is likely that a summary of the technology and its application will be required by the project stakeholders in order for them to formulate a practical view of applicability to the project. Additionally, typically plant personnel engaged in the early phase of the project such as Operations and Maintenance should also be part of this appraisal.

3.1 Application

*Wireless*HART can be applied to a wide variety of process applications in all process industries spread over differing geographical terrain. Evaluate following factors for the *Wireless*HART applications.

- Process monitoring and measurements which are at remote place and uneconomical to consider for monitoring
- Equipment Health Monitoring
- Environmental monitoring, energy management, regulatory compliance
- Extreme environmental conditions for wired installations (hot, wet and corrosive)
- Moving Rails and Test Skids

- Roatating Equipments
- Asset management, dianostics and predictive maintenance
- Simple Closed-loop control (when appropriate)
- API Seal Flush Plans
- Secondary Systems

3.2 Technology

*Wireless*HART technology can be deployed by evaluating the following factors...

- Minimizing the cost
- Ease of installation
- Reduced time for Installation and Commissioning
- Ease of Maintenance
- Ease of expansion for future I/O point (Scalability)

3.3 Operations

*Wireless*HART field network benefits Operators, shift supervisors, Production / Field Management, and facilities or engineers to collaborate to optimize process operations by collecting data in organized manner, including remote locations, to ensure that the delivery of right information to plant operations team assists them to make the right decisions to improve the plant throughput. *Wireless*HART operations benefits are...

- Covering monitoring points which are normally inaccessible to plant operator
- Increasing safety by minimizing plant operators rounds at hazardous locations and
- Better Alarm handling and reporting
- Transmitters provide better insight than gauges and switches through trending

3.4 Maintenance

There are no special maintenance requirements for the *Wireless*HART devices apart from changing the batteries.

WirlessHART devices provide greater advantage for maintenance in hazardous areas. The batteries are Intrinsically Safe and power-limited, so that they can be changed with the device in situ without risk of causing a source of ignition.

The diagnostic information provided to the Asset Management System, alerts the technician on *Wireless*HART maintenance requirements.

3.5 Appraise Phase Documentation

3.5.1 Reference documents

Customer Requirement Specification (Customer Statement of requirements)

3.5.2 Deliverables

Conceptual Design Philosophy/Architecture

Economic Analysis of technology and solutions

Project imperatives

4 Pre-FEED

In Pre-FEED, the requirements, philosophies and imperatives established in Appraise phase are further elaborated. Deployment of *Wireless*HART for identified application can be explored and verified in further detail during this phase.

Following Figure 3 shows the inputs and outputs of the Pre-FEED phase.

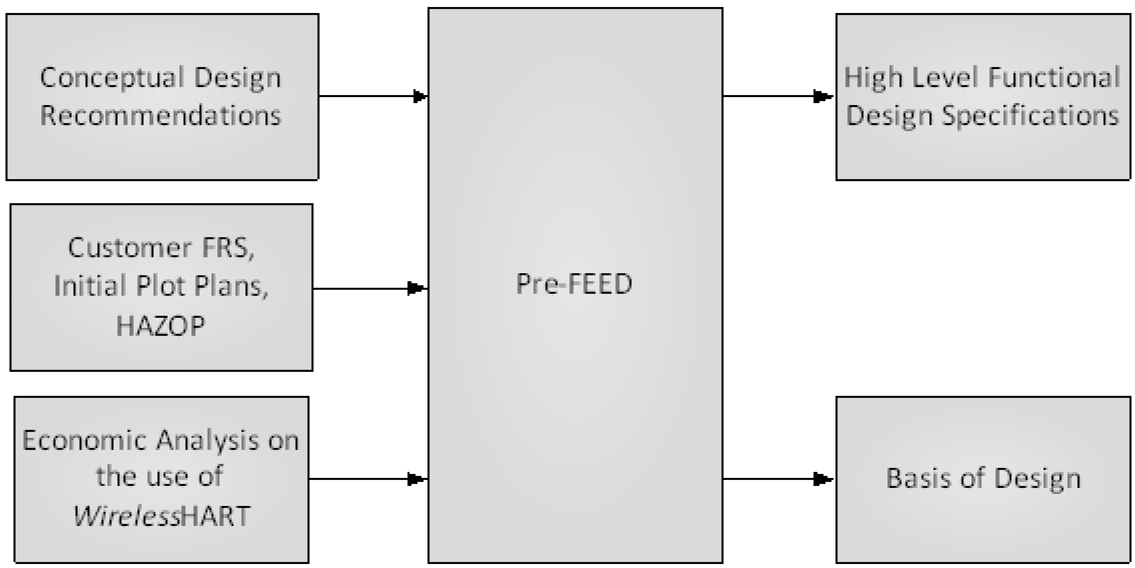


Figure 3: Pre-FEED Phase

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.

***Wireless*HART for Control and Monitoring Applications**

*Wireless*HART is designed for both control and monitoring applications. Most current use cases emphasize monitoring applications due to conservative adoption of technology to meet 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 4-1: Selecting the Right Protocol 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	Critical Control	ON –OFF Control	In- Plant Monitoring	Remote Monitoring
Conventional	Dark green	Light green	Dark green	Light green	Yellow
Fieldbus	Yellow	Light green	Dark green	Light green	Yellow
***Wireless*HART**	Yellow	Yellow	Light green	Dark green	Dark green

Legends	Based on Technical and/or Cost considerations
Dark green	**Most appropriate solution**
Light green	**Appropriate in some cases**
Yellow	**Least effective Solution**

Table 4-1: Selecting the Right Protocol

The following Table 4-2: Selecting signal types with Right Protocol shows the available technology solution for different signal types.

	Analog Inputs	Analog Output	Digital Inputs	Digital Outputs
Conventional	✓	✓	✓	✓
Fieldbus	✓	✓	✓	✓
***Wireless*HART**	✓	✗	✓	✓

Table 4-2: Selecting signal types with Right Protocol

4.1 Cost Benefit Study

*Wireless*HART and wired solutions need to be evaluated during Pre-FEED phase, for comparison from a cost and time perspective. Furthermore assessments on the benefits to schedule improvement (by phase) and change amangement should be an input to this cost benefit study.

Following factors can be considered for this comparison :

- Main Junction Box requirements
- Secondary Junction Box requirements
- Main Cable Tray requirements
- Secondary Cable Tray requirements
- Multi-core Cable requirements
- Mechanical and Civil Work for cable routing

- Power supply in system cabinets
- System Cabinet requirements
- Marshalling Cabinets
- 3D modelling review for Cable tray routing, Cable tray Engineering & Location of junction Box
- Cost of change request management
- Time and efforts for installing cable trays and cables
- Power consumption requirement
- Space requirements
- Material Weight Reduction
- System design time requirements
- Material consideration based on area classification and protection concept

In addition to the above criteria, accommodating changes is cheaper and efficient with *Wireless*HART during any project phase. Typical case studies for cost, time, power, space and weight savings are shown in Figure 4 and Figure 5. These case studies should usually consider the criteria listed above.

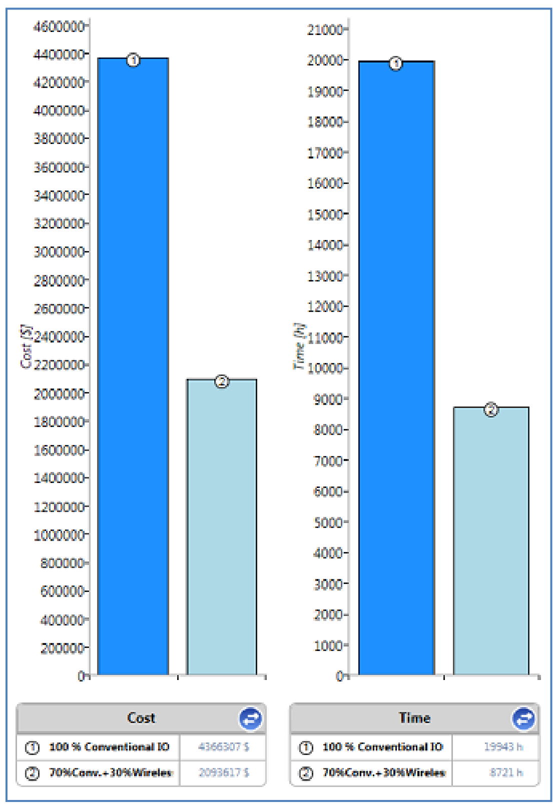


Figure 4: Case study for Time and Cost savings

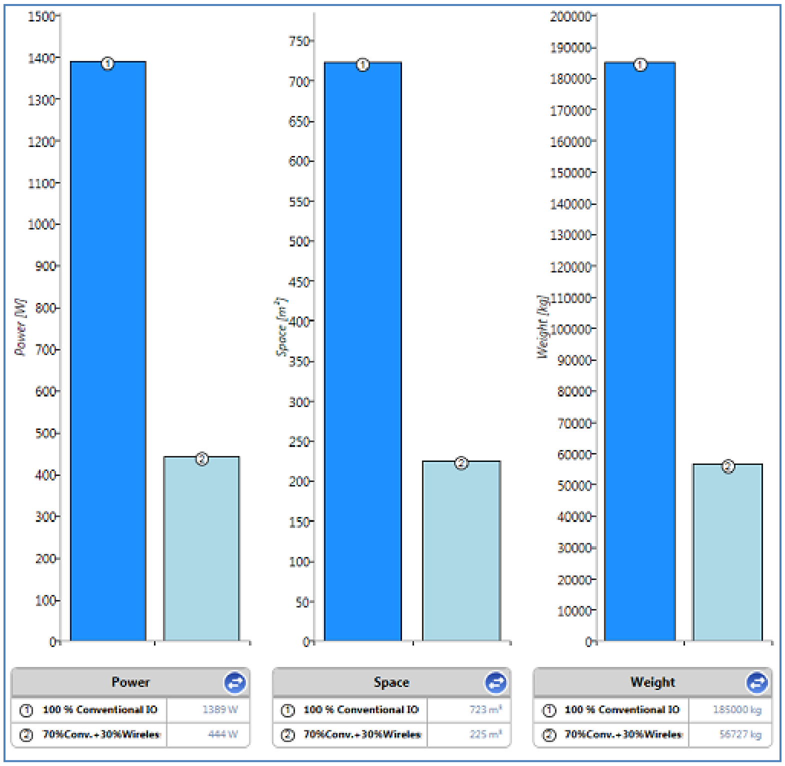


Figure 5: Case study for Power, Weight and Space savings

4.2 Preliminary Design Basis

The updated Customer Requirement Specification along with the preliminary project documents available like site plan/layout, P&IDs, Instrument index etc can be utilized to determine preliminary design basis. This includes the quantity of *Wireless*HART instruments, gateways and repeaters to create a pervasive sensing network. Assumptions on the basis of experience for similar plants/units, can be made in absence of requisite inputs.

Considering requirements of *Wireless*HART for indoor, outdoor and remote locations, the preliminary network topology for the Wireless Field Network can be worked out.

Suitable interface solution need to be considered for connection of the multiple Wireless Field Networks to the host system and AMS.

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.

4.3 Project References

Previous projects operating with *Wireless*HART, are a rich source of information and reference for new planned *Wireless*HART implementation. We can look towards these references as the first line of help to overcome specific issues encountered in new installations.

4.4 Pre-FEED Documentation and Tools

This section explains about documentation required in pre-FEED phase.

4.4.1 Reference documents

1. Initial Plot Plan
2. Initial 3D layout drawings
3. Initial P&ID
4. Instrument Index
5. Customer Specification Documents
6. Proposal Documents for cost estimates

4.4.2 Deliverables

1. Initial Wireless Field Network System Architecture
2. Measurement Signal Types
3. Bill of Quantity

5 Front End Engineering Design (FEED)

Front End Engineering Design is an important stage where key deliverables exist for wireless, for example: cost estimation , design guidelines, and specifications. Collaborative efforts put in by all stakeholders during FEED, will help in capturing all project specific requirements and avoid significant changes during the Execution phase.

The following factors can be evaluated during the FEED phase for *Wireless*HART deployment in the project.

- Environmental Considerations
- *Wireless*HART Functional Design Requirements
- Scope Definition of Engineering Execution
- *Wireless*HART Infrastructure Requirements
- Operational Requirements
- Design Inputs Documents Review
- Development of Basis for Design
- Risk Assessment and Initial Design Philosophy Review

Following Figure 6 shows the inputs and outputs of the FEED phase.

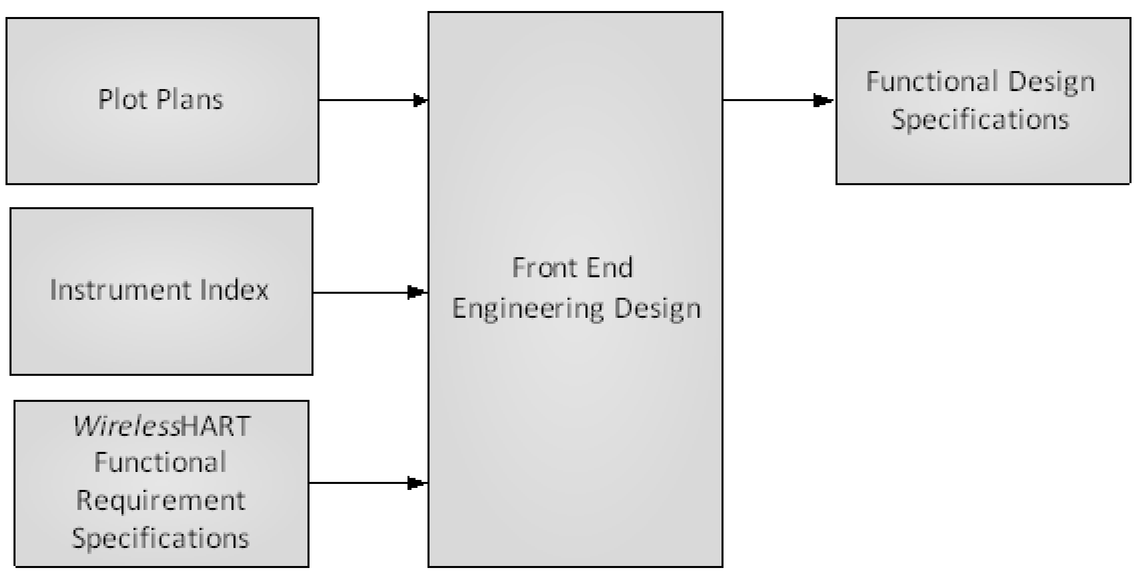


Figure 6: FEED Phase

5.1 Scope Definition of Engineering Execution

Stakeholder meetings are important to ensure all disciplines understand the scope of Wireless applications, a review of the potential benefits in key areas of the work break down structure can be discussed so that appropriate training and strategy is put in place to realise potential benefits.. Project work dependencies must be clearly distributed within the project team so that any schedule efficiencies can be realised.

In-house wireless network requirements shall be discussed to define the scope of Integration of WFN and WPN network.

Wireless Communication network availability, redundancy, *Wireless*HART equipments supply, installation, configuration and commissioning site work activities, spare requirements scope must be clearly defined.

Overall Wireless Network architecture design, Wireless device location, minimum distance and coverage between access points, network coverage and performance requirement shall be considered in the scope statement. Supplementary wireless network devices such as *Wireless*HART handheld communicator, Mobile worker supply scope shall be defined.

Determine the field device types and *Wireless*HART Signal types for project implementation. Following signal and device types shall be evaluated for *Wireless*HART implementation (refer to Emerson Literarture for the most up to date measurement types and innovations).

- Pressure
- Temperature
- Flow
- Level
- Tuning Fork Level
- Conductivity
- pH
- Corrosion
- Tank Gauging
- Guided Wave Radar
- Discrete Position Monitoring
- Discrete Inputs
- Discrete Outputs
- Acoustic (Steam Trap and PRV monitoring)
- Vibration
- Flame Detection

5.2 Environmental Considerations

Check for hazardous area classification requirements, temperature class; ambient temperature of plant.

Regional and country specifics RF frequency usage norms shall be considered.

5.3 *Wireless*HART Functional Design Requirements

During initial stage of FEED, Customer's functional requirements are translated into a network infrastructure, device charecteristics, host interfaces, and applications documented in the design specification as well as boundary conditions associated with WirelessHART applications.

5.3.1 *Wireless*HART Requirement Specifications

Following points shall be considered for developing the *Wireless*HART design.

1. Network environment and Area Classification
2. *WirelessHART* System Architecture
3. Operational requirements
4. Data requirements
5. Interfaces
6. Testing
7. Spare consideration
8. Documentation requirements
9. Training
10. *Wireless*HART network Security, reliability and interoperability requirements.

5.4 WirelessHART Infrastructure Requirements

Carryout plot plan reviews and determine the infrastructure requirements for developing

1. System Architecture
2. Wireless Field Network (IEC62591 *Wireless*HART Field Instruments) design
3. Automation Host system interface
4. Process Control Network interface

5. Asset Management System (Field Device and Field Network configuration and diagnostics

5.5 Operational Requirements

Following factors shall be considered for operational requirements

Process Monitoring and signal types

1. Device Diagnostic requirements
2. Loop response time requirements
3. DCS HMI requirements
4. Redundancy requirement
5. *Wireless*HART Network Components Requirements
6. Quantify reduction in field inspections of physical wired infrastructure (IECC60079)
7. Elimination/reduction of operator rounds

5.6 Design Inputs Documents Review

Initial design documents available for the project shall be collected from the customer to understand the project requirements. Such documents can be Plot Plans, Equipment layout plans, preliminary Instrument index, and three dimensional layout drawings.

Project team shall make sure that inputs are sufficient to define the project initial design philosophy. If documentation is inadequate then technical clarification shall be discussed with customer.

5.7 Development of Basis for Design

5.7.1 Design Guidelines for *Wireless*HART

During the FEED process, all project stakeholders should be made aware of the capability and benefits of *Wireless*HART 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 as shown in below Table 5-1: Example Criteria to identify candidate wireless applications.

	Safety Systems	Critical Control	ON –OFF Control	In- Plant Monitoring	Remote Monitoring
***Wireless*HART**	(yellow)	(yellow)	(light green)	(green)	(green)

Legends	Based on Technical and/or Cost considerations
(green)	**Most appropriate solution**
(light green)	**Appropriate in some cases**
(yellow)	**Least effective Solution**

Table 5-1: Example Criteria

Ideally, candidate *Wireless*HART 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.

Below are the key points to consider while setting the 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 0, Designing.
- Consider the *Wireless*HART field network backhaul requirement, if required.

5.7.2 Specifications

Specifications for *Wireless*HART field devices are significantly the same as wired HART devices. See Appendix B *Wireless*HART vs. Wired HART Comparison for key differences. HART instrumentation specifications are the foundation for *Wireless*HART specifications. The fundamental differences with regard 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 *Wireless*HART standard, small deviations from HART that require optional attention for the specification process, or are unique to a field device vendor.

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

Table 5-2: Differences Between Wired and *Wireless*HART

IEC 62591 *Wireless*HART 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 *Wireless*HART gateway and wireless adapter that can be generically specified as transceivers/receivers.

5.7.3 Proof of Concept Test

*Wireless*HART is well established in a comprehensive range of process plants and environments. On occasion it may be necessary for the purposes of demonstration and to establish familiarity, to conduct a proof of concept test to familiarise stakeholders to the technologies capability and applications, this can be done in a workshop setting.

5.8 Initial Design Review

Upon completion of site plot plan review, the report results gathered from various *Wireless*HART tools, proof of concepts and compliance to customer requirements shall be discussed with all stakeholders. Any requirement changes, deviations or assumptions shall also be discussed with the stakeholders. Since WirelessHART is extremely flexible it always easy to incorporate changes to the architecture.

6 Execute

During the Execute phase (Detailed Design and Testing) of a project, the engineer must account for *Wireless*HART devices per the guidelines established in the FEED, add wireless specific fields to the project database, and follow wireless field network design procedures to ensure best practices are implemented.

This section addresses the following aspects of Execute Detail design phase.

- Design Resources
- Design Guidelines
- Wireless Field Networks Design Description
    - Key Components of the Wireless Field Network Solution
    - Wireless Devices and Gateway
    - Wireless Device Selection Criteria and Datasheets
- Field Network Deployment
    - Project Environmental Considerations, Intrinsic Safety Requirements
    - Equipment Environmental Specification
    - Radio Regulatory Compliance
    - Plant Areas and candidate Areas for Further Wireless Deployments
- Host System Interface
    - Host/DCS components and architecture
    - Network Identification
    - Asset Maintenance software Interface
- Third Party Interface
- Wireless Field Network Infrastructure
    - Typical Architecture,
    - Equipment Location
    - Power Specification and Power Distribution Philosophy

  - Cable Specifications and Types
  - Field Data Backhaul Philosophy and Backhaul Specification
- Design philosophy deployment
  - Topology, Wireless Field Network Control Philosophy
  - Monitoring, Closed Loop Control
  - Module Design and Scan Rates
  - Alarm and Status Information

Following Figure 7 shows the inputs and outputs of the Detailed Design in Execute phase.

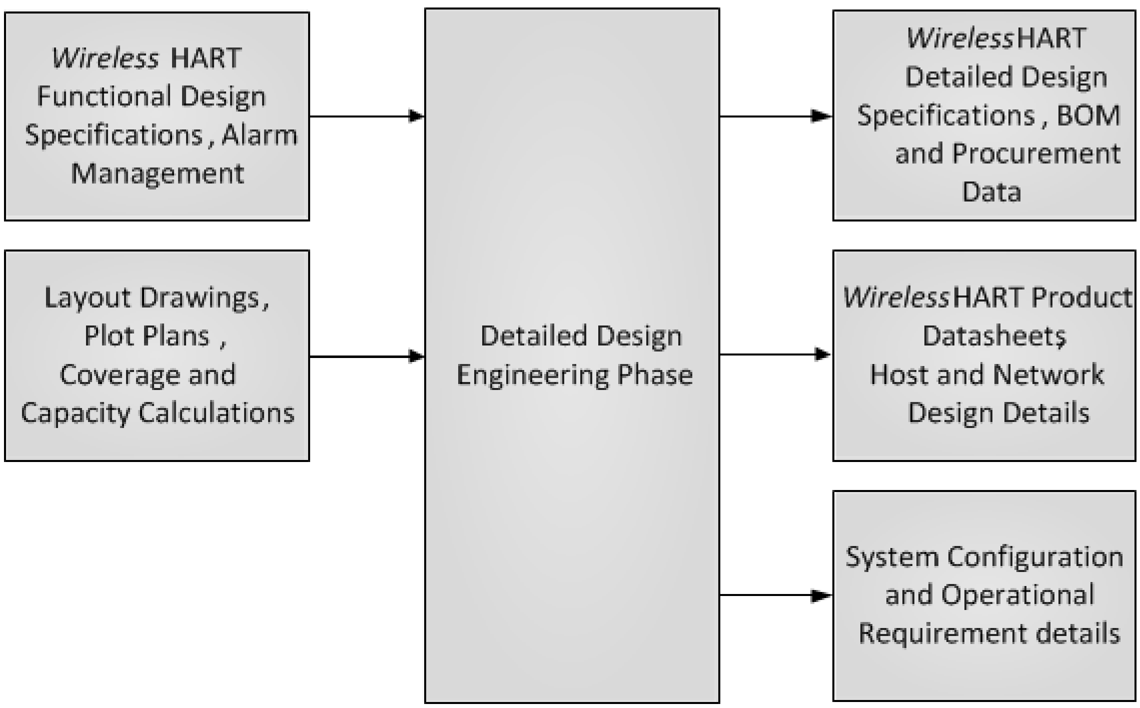


Figure 7: Execute-Detailed Design Phase

6.1 *Wireless*HART Field Network – Design Engineering Overview

There are three key steps for designing a network.

1. Scope – Decide if you need to divide wireless field networks by process unit or subsection of a process unit. Factors include:

   I. Number of devices in the process unit

II. Update rates need for wireless devices

III. Capacity of gateway

2. Design – Apply design rules to ensure optimum connectivity.

3. 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 *Wireless*HART device. Since *Wireless*HART networks become stronger, the more devices are added, the Scope step is the most critical for high density applications.

*Wireless*HART is designed for both control and monitoring applications. Refer section 2 Project Concepts for detail recommendations on using wireless control system and devices.

In general, control with *Wireless*HART is appropriate for most cases of open loop control that 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.

6.2 Design Resources

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

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

6.3 Wireless Device Selection based on process measurement

*Wireless*HART devices are available for various process measurement applications.

6.3.1 Process Monitoring & Control

- Hard to reach locations
- Process efficiency calculations
- Better insight into process
- Ad-hoc measurements
- Additional measurements from multivariable devices
- Calculated variables in devices

6.3.2 Equipment measurement

- Vibration
- Corrosion
- Oil pressure
- Air flow

6.3.3 Health and Safety Systems

- Gas Detectors
- Analyzers

6.3.4 Environmental

- Steam traps (energy usage)
- Water / Discharge Treatment
- Flow
- pH
- Stack emissions
- Relief valves

*Wireless*HART devices can be deployed in harsh environment and hazardous areas. Table 6-1: *Wireless*HART Applications below lists few examples of WirlessHART deployment. For a comprehensive list of applications, refer to the Emerson Wireless Application Guide which is available through your local Emerson project specialist.

***Wireless*HART Applications**	
Spray Water	Filter Plugging/Vapour Stream
Remote Pumps	Heat Transfer
Moving Rail Cars	Control Network Bridging
Rotating Reactor	Air Compressor
Wellhead/Heat Exchangers	Gross Oil Production Flow
Temperature Profiling/Tank Level	Blast Furnace Hearth
Gross Production Headers	Steam Trap Monitoring
Combustion Engine Emissions	Overfill Protection at Refinery
Turbine Units	State Regulation Compliance
Pump Vibration	Tank Farm Management
Rotating Lime Kiln	Boiler Box Temperature Profile
Plugged Filter Detection	Ash Dewatering Bin
Wellhead Maintenance	Steam Flow Accounting
Refinery Management	Crude Distillation Unit Steam monitoring
Roll Bearing	Calcining Unit Monitoring

***Wireless*HART Applications**	
Steam Cracker	Diesel & Kerosene production monitoring
Treated Water Usage	Rotating Calciner
Filter Condition	Pipeline Leak Detection
Pipeline System	Compressor Emissions Compliance
Remote Storage Tanks	Rotating Roaster
Cold Box	Boiler and heater gas flow
Steam Distribution Lines	Bitumen Tank Farm
Rotating Alumina Kiln	Gas & Diesel Tank Inventory Management
Power Industry Applications	NOx Emissions
Storage Tank Monitoring System	Critical Oil Movement Tank Gauging
Pipelines	Sugar Bin Motor Monitoring
Fuel Supply Systems	Gas Storage
Remote Tanks	Steam Trap & PRV Monitoring

Table 6-1: *Wireless*HART Applications

6.4 Design Criteria Development

Each wireless network field should be scoped to a single process unit.

Minimize the number of hops to the Gateway in order to reduce latency. A minimum of five wireless instruments should be within effective range of the Smart Wireless Gateway.

Each device in the network should have a minimum of three devices with potential communication paths. A mesh network gets its reliability from multiple communication pathways. Ensuring each device has multiple neighbours within range will result in the most reliable network.

Have 25 percent of wireless instruments in the network within range of Smart Wireless Gateway. Other enhancing modifications include creating a higher percentage of devices within effective range of the gateway to 35 percent or more. This clusters more devices around the gateway and ensures fewer hops and more bandwidth available to *Wireless*HART devices with fast scan rates.

6.5 Identify Candidate Measurement Points

Using the wireless guidelines established in the FEED, the design engineer should segregate all points in the project database to identify the eligible wireless IO points. 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 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. It is recommended that the update rate of the measurement shall be three times faster than 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.

6.6 Database Field for Wireless Network Assignment

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

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

Table 6-2: Definitions of Network Parameters When Using a Common Join Key shows 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 65535

Table 6-2: Definitions of Network Parameters When Using a Common Join Key

The Join Key is the most important parameter for implementing security. 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 labelling 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 *Wireless*HART 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 *Wireless*HART temperature device that reduces costs.

6.7 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 the 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 marshalling panels. Wireless field devices should be assigned to the closest gateway or to the gateway that is assigned to the process unit subsequent to the unit where the field devices reside. Once this is complete, network design best practices should be checked to ensure reliability of the network. This will be covered in detail in the *Wireless*HART 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 10 Ancillary *Wireless*HART Devices provides examples unique to *Wireless*HART 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.

6.7.1 *Wireless*HART Field Network - Design Guidelines

The *Wireless*HART network specification enables a reliable, secure, and scalable architecture. Contrary to legacy systems and point-to-point wireless networks, *Wireless*HART 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

*Wireless*HART 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 *Wireless*HART as well as Wi-Fi, Wi-Max, and more.

The best practices for network design are applicable for networks operating with mix of *Wireless*HART devices for monitoring and control with update rates from 1 seconds to 3600 seconds (60 minutes). 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.

6.8 Scoping

The same design rules that govern the segmentation of wired HART networks apply to *Wireless*HART. From a very simple perspective, all process facilities have an architecture that organizes the infrastructure as well as the automation and the people. *Wireless*HART 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.

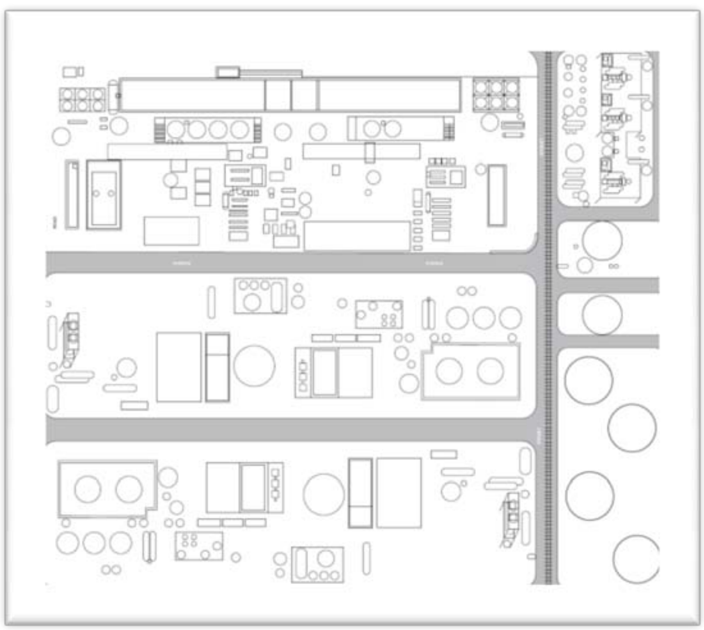


Figure 8: Example Process Facility

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 *Wireless*HART field networks to a floor. If there are 7 floors, then there are potentially seven *Wireless*HART networks.

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

- Aligns the data flow from the *Wireless*HART device through the gateway to the Host System with existing data architecture.
- Aligns *Wireless*HART tagging convention with wired HART tagging convention.
- Aligns *Wireless*HART 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 *Wireless*HART device lifecycles with wired HART life cycles including organizational responsibilities.
- Sets reasonable expectations for range between *Wireless*HART 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 and total numbers of IO points are less than the capacity of gateway, then typically a single gateway is required. 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 *Wireless*HART devices. We need to determine how many gateways are needed.

> **Note:** Some *Wireless*HART 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. 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.

2. Identify the necessary update rate of each *Wireless*HART device to meet the specifications of the application as well as battery life.

    a. Typical *Wireless*HART 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 *Wireless*HART devices per gateway if all devices are updating every 8 seconds or slower and the gateway can support 100 devices at 8 seconds.

> **Note:** 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.

4. Determine and apply any guidelines on spare capacity. If the design rules for the project state that I/O components should have 40% spare capacity, then note this value for the following calculation.

5. Use the following calculation to determine the number of gateways.

    # gateway=ROUNDUP((Total *Wireless*HART devices in process unit)/(gateway capacity*(1-spare capacity requirement)))needed:

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

For the example above, three gateways are needed.

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

This formula can be entered into Microsoft Excel.

6. 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 marshalling panels and junction boxes. In Figure 9, the master drawing, the process unit has 16 subsections labelled 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.

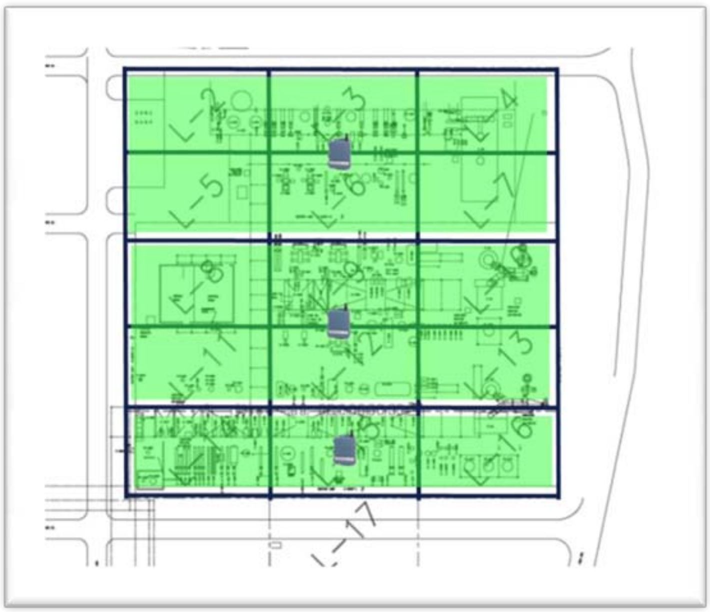


Figure 9: Process with 3 *Wireless*HART Networks and good gateway placement

This example shows three *Wireless*HART gateways supporting three *Wireless*HART 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.

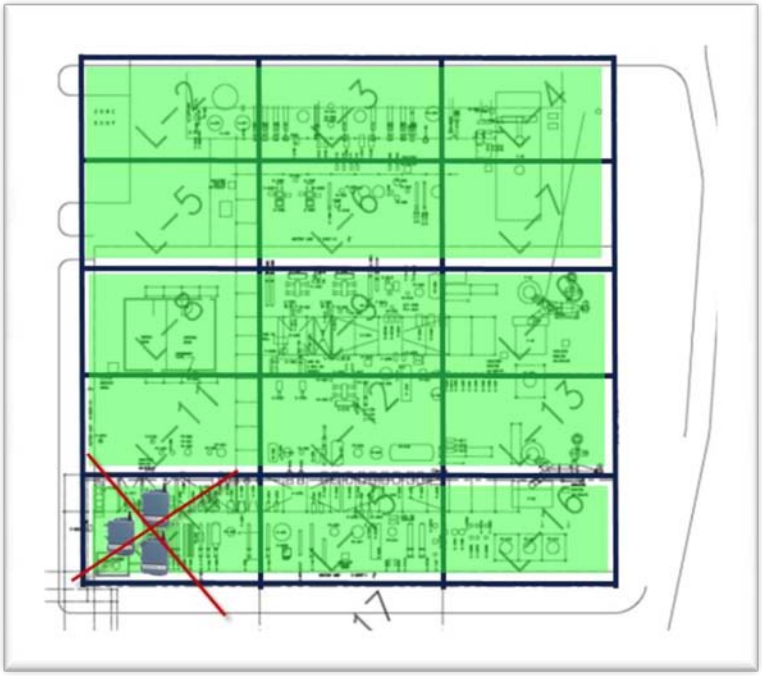


Figure 10: Process with 3 *Wireless*HART gateways and poor gateway placement

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 that 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.

*Wireless*HART 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 *Wireless*HART devices and management with existing process facility, organization, and work practices.
- Every *Wireless*HART gateway in a facility must have a unique Network ID to properly segment the *Wireless*HART 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 *Wireless*HART gateways.

6.9 Detailed Design Specifications

Upon completion of site study report review and considering the control system requirements, Detail Design Specifications shall be prepared. Detail design shall cover overall wireless mesh architecture including the detailed network infrastructure, *Wireless*HART devices and network hardware and software specifications, network integration method, network security specification, network monitoring tools and documentation requirements.

6.9.1 Designing

Effective Device Range

The following design rules are intended to be very conservative and are based on real-world deployments of *Wireless*HART field networks. The effective range of a device is the typical linear distance between *Wireless*HART field devices when in the presence of process infrastructure. Typically, if *Wireless*HART 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 neighbouring 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 *Wireless*HART 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 *Wireless*HART devices isolated from the network by an enclosure, consider scoping a network inside of the facility. Small, fibreglass 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 *Wireless*HART devices allow operation for several years without replacing a battery module, but also limit the output power of the radio and maximum range. Because *Wireless*HART 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 neighbouring 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 *Wireless*HART network should have a minimum of 5 *Wireless*HART devices within effective range of the gateway. Networks will work properly with less than 5 *Wireless*HART 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 *Wireless*HART 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 *Wireless*HART 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.

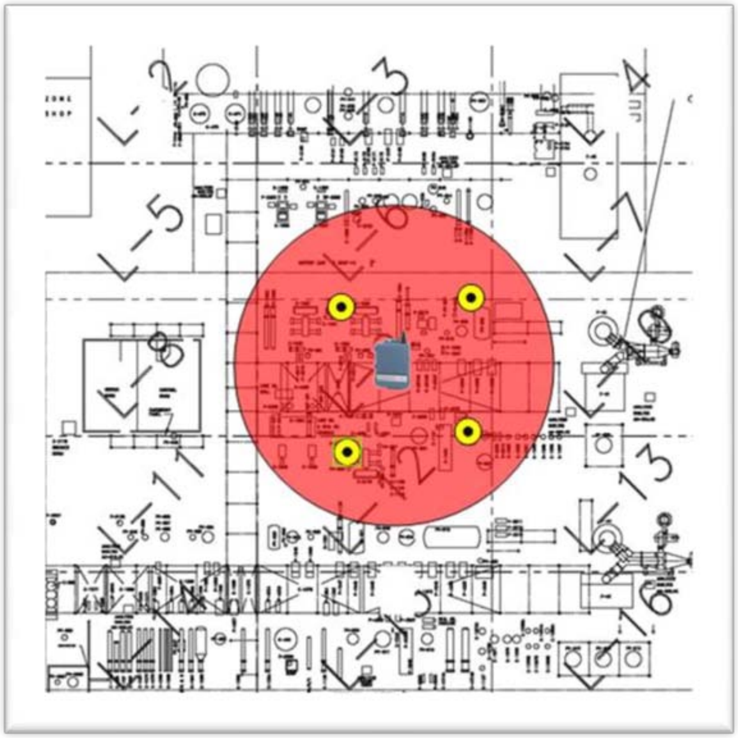


Figure 11: Process With Rule of 5 Broken

2. Rule of 3 – Every *Wireless*HART device should have a minimum of 3 neighbours with in 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 *Wireless*HART device that does not have 3 neighbours. For reliability, it is essential for every *Wireless*HART to have 2 paths during operation to ensure a path of redundancy and diversity. The Rule of 3 when designing ensures concentration of devices.

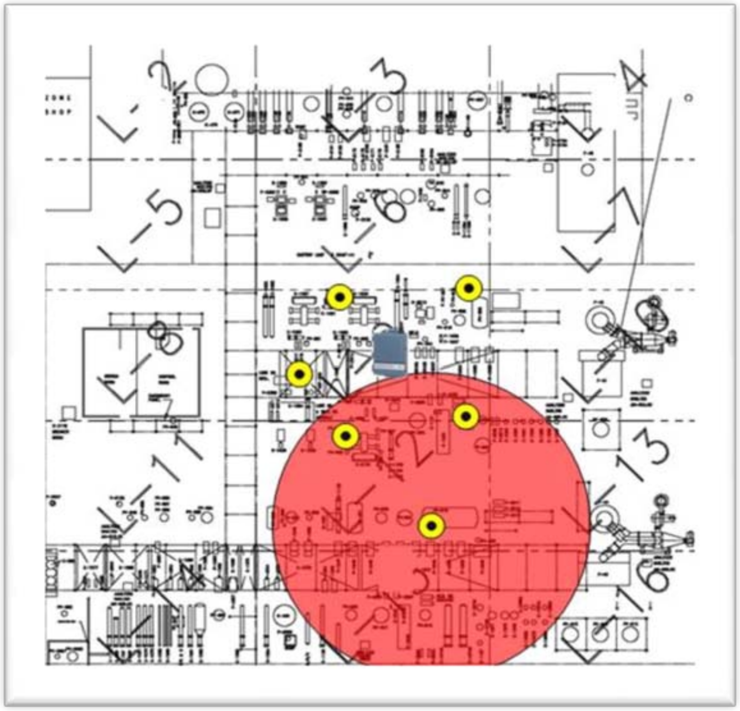


Figure 12: Process With Rule of 3 Broken

3. Rule of Percentages - Every *Wireless*HART 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. *Wireless*HART 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.

    I. 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

*Wireless*HART 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 *Wireless*HART 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.

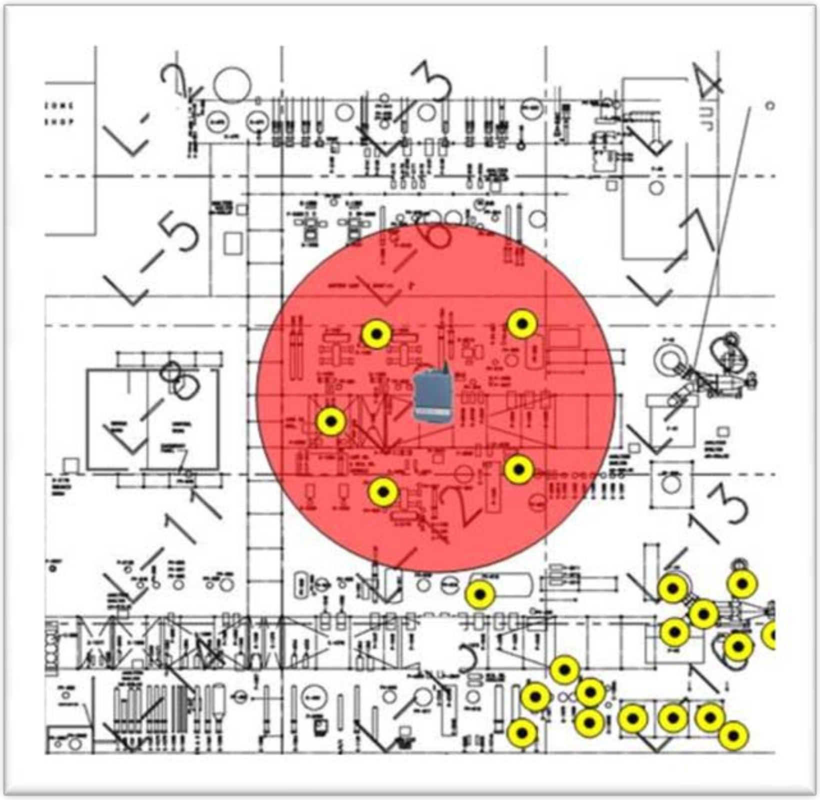


Figure 13: Process With Rule of Percentages is Broken

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 *Wireless*HART instrumentation. In this case, there may not be a convenient host system integration point at the centre 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.

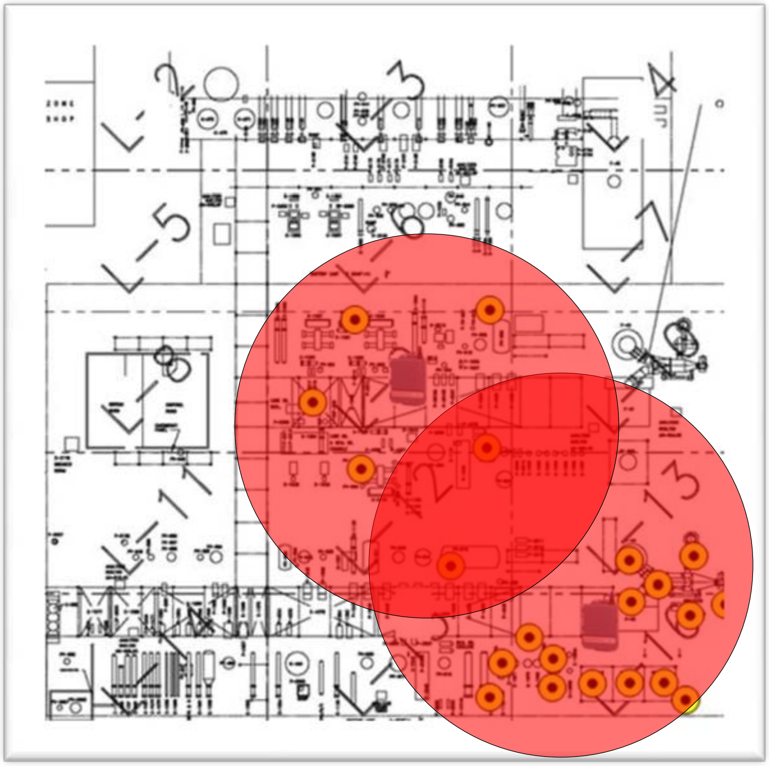


Figure 14: Process With Two Gateways

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.

6.9.2 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 addition consideration provided in this text ensures higher path stability that can be confirmed once the network is deployed. Most *Wireless*HART vendors provide the means to verify after installation.

6.9.3 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 form 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 are as follows:

- 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 that the control command was received and executed.

6.10 Spare Capacity and Expansion

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

6.11 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: Process Standard Design (Left). Stress-Tested (Right)

The self-organizing mesh technology allows for more *Wireless*HART field devices to be added to a network for the purposes of automation, and provides the means for simple design correction to 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 *Wireless*HART 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. *Wireless*HART adapters may make cost-effective repeaters if local power is available.

6.12 *Wireless*HART Availability and Redundancy

The *Wireless*HART 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 *Wireless*HART field device with typical performance approaching 100%.

The following are considerations for maximizing system availability between the host system and the *Wireless*HART 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.

6.13 *Wireless*HART 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.

6.14 Alarm Handling with *Wireless*HART Devices

Most modern industrial complexes will have a range of different methods for bringing sensor related data back in to the central automation system. This may range from conventional analog (4-20mA) and discrete signals to more sophisticated digital transmission methods such as Foundation Fieldbus, Profibus and *Wireless*HART. While all signalling methods have some degree of fallibility the important consideration should be that whatever technology is used, a process deviation is correctly detected, communicated and acted upon in a timely manner.

Digital devices have rich features which are not traditionally available with non smart 4-20mA devices. Smart devices using HART or Foundation Fieldbus technologies are capable of providing predictive alerts to warn of potential sensor failure which may lead to degraded process and operations. Additional non process related stresses may also impact the measurement quality for instance:

- Crushed Cables
- Excessive Length
- Mechanical Fatigue
- Poor Glanding
- Cable Routing Complexity
- Routing between moving components
- Supporting Cable Weight
- Grounding

Intermittent and potentially unrevealed failures can be difficult to trace, costly to fix and lead to poor decisions by operators

Wireless technology is also susceptible to environmental influence, for instance:

- Propagation
- Attenuation
- Distortion
- Interference

The benefit of IEC62591 *Wireless*HART is that failures are detectable. Erroneous data is not possible due to corruption of the data payload as measuring integrity checking indicates bad data. The sensing technology and process interface arrangements are identical to wired sensor transmitters therefore sensor erosion/drift issues are the same as conventional analogue non smart devices. As previously mentioned IEC62591 *Wireless*HART provides a predictable capability to detect and advice on potential failure.

In either case wired or wireless, utilising best practice recommendations can reduce the probability of failure.

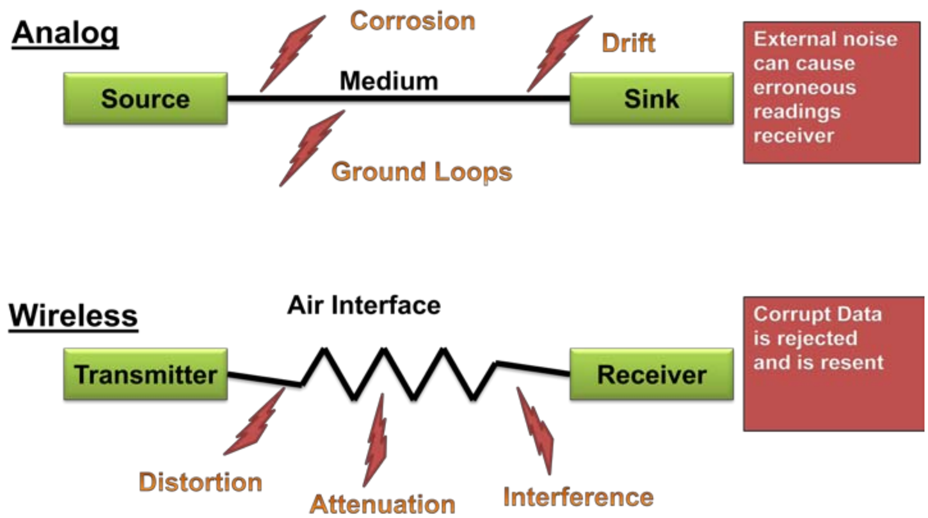


Figure 16: Alarm Propagation to the system

6.14.1 Alarm Recommendations for Process Plant

Wireless devices have periodic updates which vary from 1 second to many minutes. For the purpose of this discussion it is considered that the wireless point will have a fixed scan rate, i.e. a preconfigured rate at which the device sensor is energised and a reading of the process is made, (i.e. smart updates are not applicable). When assigning an alarm to a process variable below are some factors which will come into consideration when determining an appropriate scan rate (DCS control algorithm or wireless device):

1. Process Time: What is the expected rate of change for the process variable? How rapidly does a process variable approach abnormal operating conditions? This should accommodate sudden process swing which may move the process variable outside the normal operating range.

2. Operator Response Time: what is the time for an operator to respond to an alarm and correct the fault?

Generally to satisfy the conditions, the device scan rate must be at least {4} x times the process time constant (including dead time). In practice the operator response time is likely to be several scans longer than this and does not need to feature in this calculation.

Factors affecting the multiplier are:

1. Ability to synchronise communications with alarm processing functions

2. Ability to send data by exception

6.14.2 Alarm Priority

Assignment of alarm priority must follow the criteria as defined in the Alarm Philosophy for the plant. The subsequent alarm rationalisation exercise will define the purpose, intent and consequence of each alarm.

Priority	EEMUA %	Comment
Low	80	Wireless Possible Monitoring and assessed control loops
Medium	15	Conventional Wired
High	5	Conventional Wired

Table 6-3: Alarm Priority

Note: EEMUA 191 (The Engineering Equipment and Materials Users' Association Publication 191 for Alarm Systems)

Generally between 65% to 80% of alarms will be low priority with minimal risk and consequence, and therefore these points are all possible candidate points for *Wireless*HART devices.

6.15 Datasheet Parameters for *Wireless*HART Transmitter

Following Table 6-4: Part of *Wireless*HART Transmitter specification of datasheet shows the typical *Wireless*HART Transmitter section specification of datasheet.

TRANSMITTER	22	Scan Rates	1 seconds ☐ 2 seconds ☐ 4 seconds ■ 8 seconds ☐ 16 seconds ☐ 32 secondsor ☐
			1 minutes ☐ (Note: 2.4 GHz DSSS WirelessHart allows for 1,2,4,8,16,32 seconds or 1 to 60
	23	Operating Frequency and	2.4 GHz DSSS, IEC 62591 (Wireless HART)
	24	Antenna Type	Omnidirection Antenna ■ High-Gain Antenna ☐ Directional Antenna ☐
	25	Diaphragm/ Wetted Material	Hastealloy C276
	26	Type of Protection	Intrinsic Safety
	27	Communication Protocol	Wireless HART
	28	Body Material	316L SST
	29	Enclosure Type Class	IP66
	30	Transmitter Output	Wireless with user Configurable transmit rate
	31	Hazardous Protection	ZONE 2 IIC T4
	32	Loop Power Supply	Lithium Battery ■ Energy Harvesting ☐ Wired Power ☐
	33	Accuracy	=/- 0.055% of F.S
	34	Network ID	☐☐☐☐ (0000-32000)
	35	Join Key	☐☐☐☐☐☐☐☐ ☐☐☐☐☐☐☐☐ ☐☐☐☐☐☐☐☐
			☐☐☐☐☐☐☐☐
	36	Body Type	
	37	Digital Communication	IEC 62591
	38	Digital Display	Pressure ■ % of Range ☐ Scaled Variable ☐ Sensor Temperature ☐ Supply Voltage ☐
	39	Output Information	Write Project: Enabled ☐ Disabled ■
ALARM	40	Pressure Process Alert	LRL≤LO LO Alert≤ LO Alert≤HI HI Aler≤URL
			ON ☐ OFF ■
			LO LO Set Point: Deadband: (Engineering units)
			LO Set Point: Deadband: (Engineering units)
			HI Set Point: Deadband: (Engineering units)
			HI HI Set Point: Deadband: (Engineering units)

Table 6-4: Part of *Wireless*HART Transmitter specification of datasheet

Note: Inclusion of 'join key' in the datasheet above is optional.

6.16 Tools and Documentation

This section explains about the input Documentations and tools required in detailed design phase.

6.16.1 Functional Design Specifications

Functional design Specifications developed in FEED stage shall be used as reference for detailed design.

6.16.2 Instrument Index/Database

Refer SPI 2009 documentation for recommendations for additional fields not typically included in wired HART specifications.

6.16.3 Instrument Data Sheets

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

Specification Field	Typical HART Field
Update Rates	1,2,4,8,16,32,64+ sec
Power Supply	Intrinsically Safe, Field Replaceable Battery
Communication Type	IEC 62591

Table 6-5: *Wireless*HART 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 *Wireless*HART. See Appendix A for a specification sheet example for a *Wireless*HART gateway.

6.17 Testing

This section explains the *Wireless*HART testing during FAT, Site installation and Commissioning and SAT .

Testing Phase is important to confirm that the delivered *Wireless*HART solution meets the customer requirements and design references used in the project. Prepare the test plan which shall include the description of the stages of WirlessHART scope testing, hardware FAT, software FAT, 3rd party interface testing.

Following Figure 17 shows the inputs and outputs of the Testing in Execute phase.

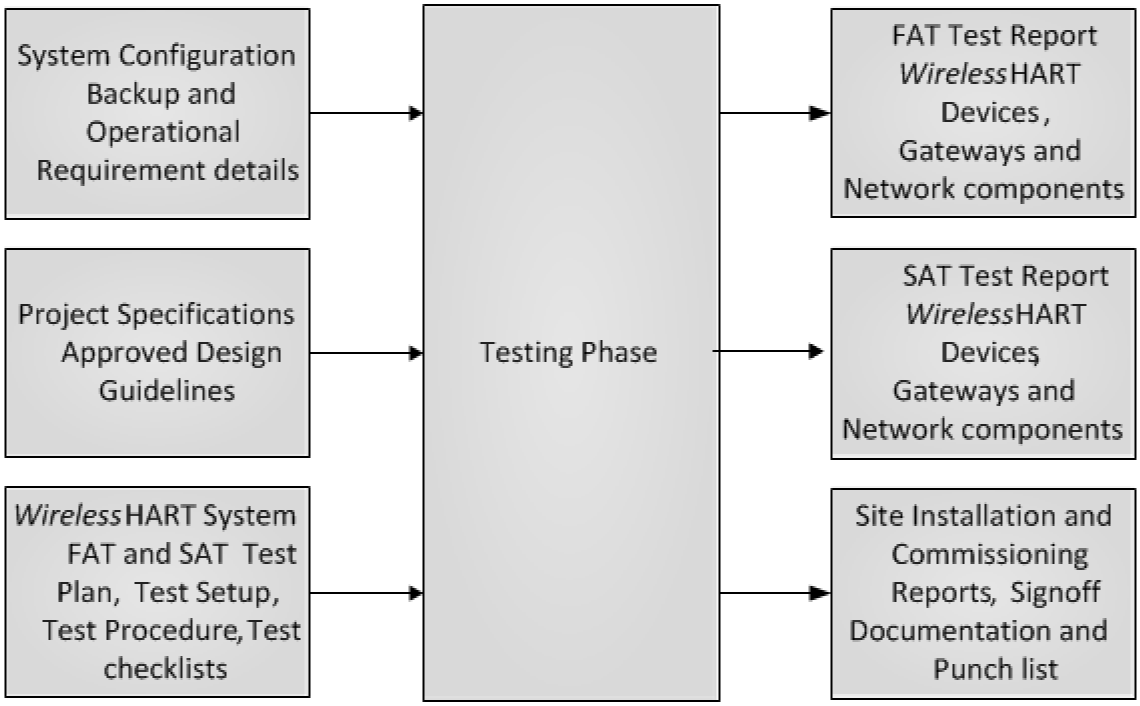


Figure 17: Execute - Testing

6.18 Factory Acceptance Test (FAT)

Factory Acceptance Tests require establishing a connection between the Gateway and the Host Systems. *Wireless*HART 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.

The key deliverable of a factory acceptance test (FAT) is the integration of data from *Wireless*HART 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.

6.18.1 Factory Staging

The following are basic requirements for factory staging:

1. A sample of all applications, gateways and *Wireless*HART devices.
2. Approved test plan, test procedure and test acceptance criteria.
3. HART Field Communicator and user interface to the *Wireless*HART Gateway.

6.18.2 Assumptions

Below are assumptions for Factory Acceptance Test:

- Network topology testing is covered as part of the Site Acceptance Test.
- *Wireless*HART 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.

6.18.3 Factory Acceptance Test (FAT) Requirements

The following are key requirements of 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 *Wireless*HART devices that are new to the market.

6.18.4 FAT Network Configuration

*Wireless*HART device shall be configured with the Network ID and Join Key and sufficient time for network polling. The transmitter shall be detected by the network. To verify connectivity, open the host interface and check if *Wireless*HART device is available.

- FAT network shall cover testing aspects for hardware, configuration, communication, security.
- Before setting up the network, carry out the pre power up check for each component on the network.

6.18.5 Wireless Network Troubleshooting

If *Wireles*sHART Device is not joining the network then follow steps listed below .

- Verify network ID and join key
- Wait longer (30 min.)
- Enable High Speed Operation (Active Advertising) on Smart Wireless Gateway
- Check battery
- Verify device is within range of at least one other device

- Verify network is in active network advertise
- Power Cycle device to try again
- Verify device is configured to join. Send the “Force Join” command to the device

6.18.6 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 FAT:

1. Power the gateway
2. Add one of each type of *Wireless*HART device to the network and verify proper connectivity. All gateway fields for data from the *Wireless*HART 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 *Wireless*HART device into the Host System Application.
    I. Optional additional procedure is to change process variables in the *Wireless*HART 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 to the gateway are complete.
7. Test integration into an asset management solution if applicable.
    I. Verify each *Wireless*HART device can be properly accessed and configured via the asset management solution.

8. Add any additional procedures to verify control narratives and monitoring narratives.

6.18.7 FAT Tools

- Handheld Communicator
- Multi-meter
- Computer setup with Gateway/card interface software

6.18.8 FAT Documentation and Reports

- FAT Plan
- FAT Procedure
- FAT Checklist

6.19 Site Installation

In general, *Wireless*HART 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 *Wireless*HART enables wireless field devices to self-route through the process environment and reroute when the environment changes. Always refer the instruction manual of the *Wireless*HART device for specific considerations. This is covered in detail in *Wireless*HART Field Network Design Guidelines.

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

*Wireless*HART 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.

*Wireless*HART 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.

6.20 Site Installation Plan

6.20.1 Installation Considerations

1. Use the device specific instrument manuals for installation instructions.
2. Install instruments and process connections. Take cautions to keep the antenna from being directly mounted against metal surfaces.
3. Fiberglass instrument enclosures provide no significant impact to wireless performance.
4. If wireless instruments are mounted inside a building, relative to the majority of the wireless instruments, a passive antenna or additional repeaters should be used to ensure good connectivity.

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

6.21 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, *Wireless*HART devices are installed per the practices of wired HART devices. Always refer the product manual for details.

*Wireless*HART 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.

*Wireless*HART devices can be installed in close proximity to each other without causing interference. The self-organizing mesh scheduling of *Wireless*HART 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 *Wireless*HART gateway antenna or *Wireless*HART 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.

For achieving better network bandwidth check for following:

- Reduce the Update Rate on transmitter
- Increase communication paths by adding more wireless points
- Check that device has been online for at least an hour
- Check that device is not routing through a "limited" routing node
- Wireless Connection Test Procedure

6.22 Wireless Connection Test Procedure

Before beginning the wireless connection test procedure, verify the *Wireless*HART 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 *Wireless*HART 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. 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 proper bandwidth of the device. The gateway should have an indication.

3. Verify each device has a minimum of two neighbours. 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 the basic steps below:

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.

    I. 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.

6. Either reduce the update rate of the field device or increase the fastest allowed update rate on the gateway.

6.23 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.

6.24 Lightning Protection

1. Ensure that the *Wireless*HART device bodies are correctly grounded

2. The installation manuals of all *Wireless*HART devices should be consulted prior to installation.

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

4. Ensure adequate protection is provided between the *Wireless*HART gateways and host system connection as a lightning strike could damage more than just the *Wireless*HART gateway

5. 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.

6.25 Device Parameter Configuration Verification

Device Parameters verification is important before putting in to service. Device parameter list will change based on device type. However, following is the list of common *Wireless*HART parameters that can be used for verification. These parameters can be verified along with device datasheet specifications.

- TAG
- Device ID
- Network ID
- Network Join Status
- Wireless Mode
- Join Mode
- Number of Available Neighbours
- Number of Advertisements Heard
- Number of Join Attempts
- Manufacturer
- Device Type
- Device Revision
- Software Revision
- Hardware Revision
- Identification
- Revisions
- Radio
- Sensor information
- Electronics Temperature
- Supply Voltage
- Supply Voltage Status
- Last Update Time

6.26 Loop Checkout/Site Integration Tests

Once *Wireless*HART 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 devices 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.

6.27 Bench Simulation Testing

Each *Wireless*HART 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.

6.28 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.

6.29 Removal of Redundant Equipment

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

6.30 Pre-Commissioning

6.30.1 Pre-Commissioning Requirements

1. Determine which *Wireless*HART instruments and *Wireless*HART Gateways are installed correctly. Crosscheck instrumentation against Instrument Data Sheets.

2. Conduct site walk-through to determine *Wireless*HART Gateway location and any infrastructure barriers. Ensure local power is available for *Wireless*HART devices and Gateways and Plant Network radios.

3. Determine Smart Wireless Gateway connection back to host system (Serial, Ethernet, WiFi Network).

4. Determine if other forms of existing wireless present in and around the location that may cause interference (Cell phone towers, high power radio transmitters)

6.30.2 Defining *Wireless*HART Pre-commissioning Methods and Acceptance

Define the pre-commissioning activities for the following:

- **Devices:**

  Confirm device installation and configuration as per customer requirements and specifications.

- **Network:**

  Confirm the network is up and running in the Smart Wireless Gateway. Verify each device is connected and network meets best practices (neighbours, hops etc).

- **Security:**

  Verify security set-up and configure. Configure firewall as per requirements (optional).

- **Power up sequence:**

  The battery should not be installed on any wireless device until the Wireless Gateway is installed and functioning properly. Wireless devices should also be powered up in order of proximity from the Wireless Gateway, beginning with the closest. This will result in a simpler and faster network installation. Enable Active Advertising on the Gateway to ensure that new devices join the network faster.

6.31 Site Acceptance Test (SAT)

The site acceptance shall cover primarily all *Wireless*HART infrastructures, associated hardware, software and operational checks.

- Verify the installed infrastructure as BOM.
- Verify network communication
- Verify the correct configuration of *Wireless*HART network components.
- Data communications between wireless devices and DCS
- Verify faceplates and all HMI elements for connected wireless devices
- Prepare SAT report and signoff with customer.

Documentation for Site Acceptance Test documentation:

- SAT Plan
- SAT Procedure
- SAT Checklist

6.32 Commissioning and Start-up

*Wireless*HART gateways segment the commissioning process. Since gateways connect the wireless field devices to the host system, *Wireless*HART 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 *Wireless*HART device can confirm the device is operational.

6.32.1 Wireless Network Integration with HMI and Loop check

Verify device variables in the Smart Wireless Gateway. Also check parameters like TAG, Device ID, Network ID, Network Join Status and Device Status. Verify device operation from three places:

- At the device via the Local Display
- Using the Hand held communicator
- Host system user interface.

6.32.2 Integrating Host and Field Networks

- Configure the Wireless Gateway or wireless interface network ID and join key and verify connection.
- Check the installation of the Wireless Gateway and power up.
- Host Integration of gateways through Ethernet connectivity
- Host Integration of gateways through Serial connectivity
- Host Integration gateways through Fiber optics
- Host integration over wi-fi link.

6.32.3 Onsite Wireless Network Reliability Tests

1. At device level check

   Join Status, Wireless Mode, Join Mode, Number of Available Neighbours, Number of Advertisements Heard, Number of Join Attempts.

2. Duration based tests

   Carry out following tests

- Loop response time
- Consistency in process data update. Network and device uptime confirmations.
- Obstruction tests
- Network uptime test for 2,4,8,12, 24 Hours

3. Wireless Site Execution

   Maintain the records for following topics

   - System files (including diagnostics)
   - Diagnostics
   - Validation form
   - Wireless Deviation Register
   - Punch Lists
   - Final Bill of material list

7 Operate

Operate phase for *Wireless*HART network covers aspects like *Wireless*HART asset Management, Data Management concepts, Maintenance Practices, etc.

Following Figure 18 shows the inputs and outputs of the Operation phase.

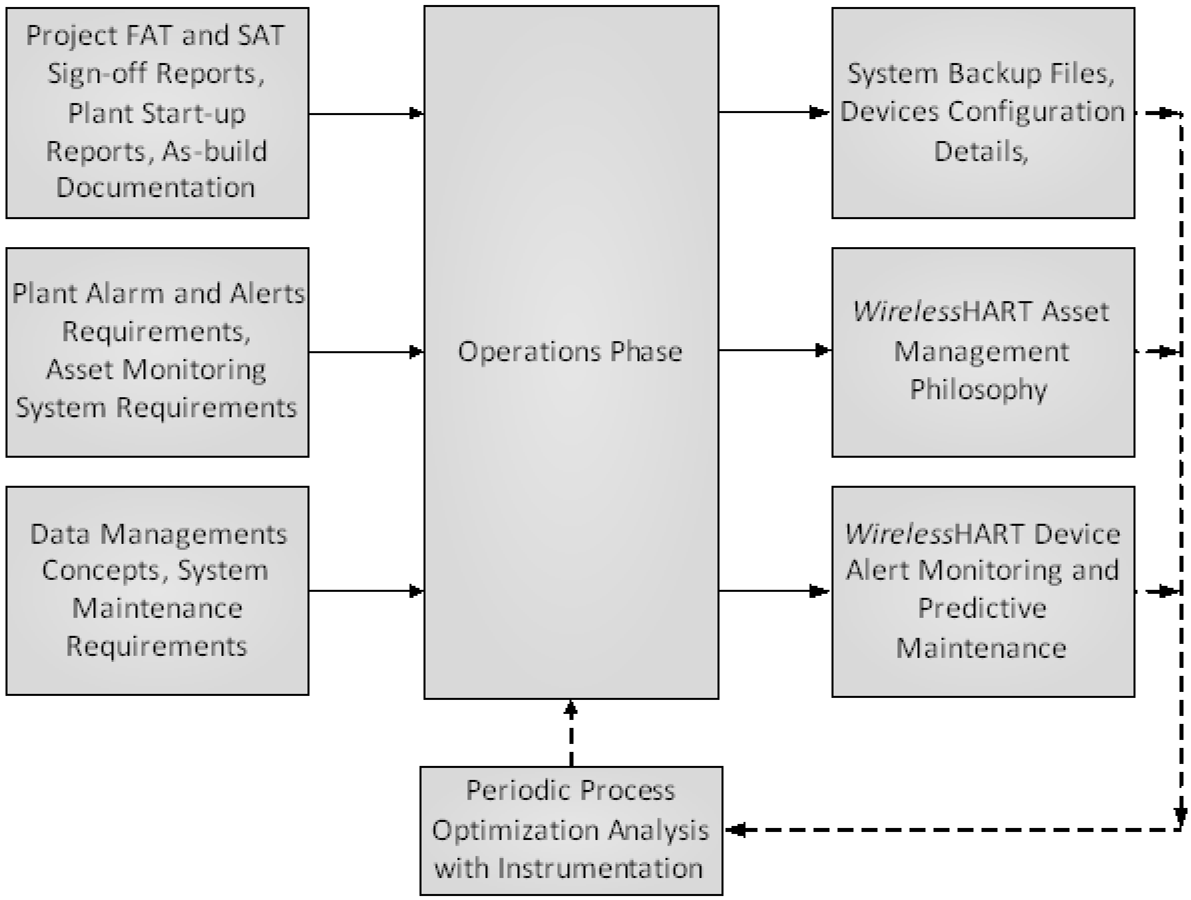


Figure 18: Operate Phase

7.1 Asset Monitoring

With the use of Wireless Asset Management Applications, users can plan, customize, visualize and manage smart wireless networks. Asset Management system handles predictive diagnostics, documentation, calibration management, and device configuration for managing field instruments. Asset management system allows changing, storing, comparing, and transferring device configurations without ever going into the field. Streamline the calibration by defining device test schemes, scheduling device calibration, and managing device calibration data.

With the Asset Management System, wireless diagnostics are organized across multiple Wireless Gateways. Asset monitoring system provides detail reports. Below are the lists of fields you can use in your reports:

- Device tag / Gateway
- Battery voltage
- Update rate
- Ambient temperature
- Status
- Parents / children / neighbours

7.2 Alarm and Alerts Philosophy

Configure Process Alerts

Process alerts allow the transmitter to indicate when the configured data point is exceeded. Process alerts can be set for process variable and secondary variable. For example, for pressure transmitter, process alerts can be set for pressure, temperature, or both. The alert will reset once the value returns within range.

Device Alert displayed on:

- Field Communicator
- Asset management system status screen
- In the error section of the LCD Display of instrument

Following alarms configuration can be used for *Wireless*HART device.

- HI HI Alarm, HI Alarm, LO Alarm, LOLO Alarm

7.3 Data Management Concepts

During normal operation *Wireless*HART system configuration data shall be maintained. Periodic system backup should used from system software. Device configuration and audit trails shall be maintained.

Maintenance, calibration and inventory documentation requirements shall be used from host system capabilities.

7.4 Maintenance Practices

Maintain each *Wireless*HART device per the device manual.

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.

8 Project Management

This section explains Project Management aspects for *Wireless*HART Projects.

8.1 *Wireless*HART Project Management Overview

This section summarizes the overall concept of *Wireless*HART project management.

Customer Requirements, Compliance and Assumptions

Customer requirements document should be evaluated thoroughly based on parameters like past project knowledgebase, system and technology capabilities, project best practices etc. Regional and country specific requirements must be understood correctly.

Compliance to Customer requirements document shall be prepared. Valid assumptions shall be used and discussed with the customer where information is uncertain.

8.2 Work Breakdown Structure and 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)
- Reduced labour (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 *Wireless*HART gateway essentially provides spare I/O capacity)

8.3 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.

8.4 Project Scheduling

1. Review schedules to recognize:

   I. Limited infrastructure installation and hence reduced material and installation scope.

   II. 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.

   I. Eliminated scheduling and expediting associated with marshalling cabinets.

5. Schedule should reflect eliminated activities and simplified FAT, SAT and SIT (site integration test) on areas where wireless has been extensively deployed.

8.5 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

Responsibility and Skills matrix shall be developed for each phase of the project. End user, EPC Contractor and Main Automation Vendor shall define the Roles and Responsibility matrix for each task of project lifecycle like pre-FEED, FEED and Exceute phase of project. Stakeholders shall assign with roles like:

- Responsible
- Accountable
- Consulted
- Informed

8.6 Managing Project Change Requests

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.

8.7 Progress Reviews and Reporting

Define the project execution stages for review. Prepare review reports and inform all stakeholders.

8.8 Customer Deliverables

Prepare the list of documentation to be submitted to customer.

8.9 Training

Include the training requirements for Plant operators, Maintenance team and Engineering team.

8.10 *Wireless*HART Procurement and Contract Plan

Check completeness of contract dcouments like Technical Specifications, Delivery requirement (time & location), Quote requirement (Expected date and validity, regional regulations for *Wireless*HART other T&C's), and Documentation & Certification requirements.

8.11 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.

8.12 Documentation Requirements in Project Execution

- Equipment 3D layouts
- Site Plan
- Drawings
- Control Narratives
- Project Management Plan
- Site execution plan
- Testing (FAT and SAT)
- Installation procedure and checklists

- Commissioning and start-up checklists
- Sign off documents

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

See 13 Documenting in Intergraph SPI 2009 for a complete treatment of documentation.

8.12.1 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:

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

2. 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.

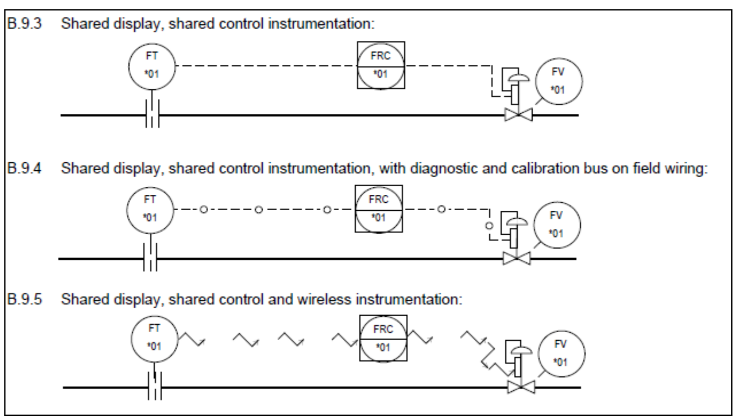


Figure 19: ISA 5.1 Wireless Drawing

3. The implementation of *Wireless*HART requires far fewer components, making drawings simpler.

PART II

*Wireless*HART Field Network Components

9 Field Device Requirements

9.1 Support for *Wireless*HART Functionality

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

9.1.1 Device Diagnostics

HART Diagnostics

*Wireless*HART devices contain similar or a subset of all of the diagnostics of wired HART devices expect configurable alarms, device, battery and alerts for the process. 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 *Wireless*HART 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 *Wireless*HART 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.

9.2 Device Mounting

Device mounting considerations

Verify the process application such as Gas, Liquid and Steam flowing through the process lines.

Check for device process connection requirements and ensure the process line isolation before installation.

If the transmitter installation requires assembly of the process flanges, manifolds, or flange adapters, follow Device Manual assembly guidelines to ensure a tight seal for optimal performance characteristics of the transmitters.

Antenna position

Position the antenna vertically, either straight up or straight down. The antenna should be approximately 3 ft. (1 m) from any large structure or building to allow clear communication to other devices.

Mounting High Gain Remote Antenna

The high gain, remote antenna options provide flexibility for mounting the *Wireless*HART Device based on wireless connectivity, location, and lightning protection requirements.

Choose location where the remote antenna has optimal wireless performance. Ideally this will be 15-25 ft (4.6 - 7.6 m) above the ground or 6 ft (2 m) above obstructions or major infrastructure.

Check for weather proofing/lightning arrester requirements.

9.3 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 with in 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.

For achieving longer battery life check for following recommendations:

- Check that "Power Always On" mode is off.
- Verify device is not installed in extreme temperatures.
- Verify that device is not a network pinch point.
- Check for excessive network rejoins due to poor connectivity.

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. 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.

9.4 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.

9.5 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.

9.6 Accessibility

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

Below are general requirements for *Wireless*HART field devices.

- *Wireless*HART devices shall be locally accessible with HART field communicators that support wired and *Wireless*HART devices.
- *Wireless*HART devices shall be manageable with remote asset management systems that access the *Wireless*HART device via the gateway and through the *Wireless*HART network.
- *Wireless*HART 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.

9.7 Manufacturer Documentation

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

10 Ancillary *Wireless*HART Devices

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 *Wireless*HART adapters.

10.1 Gateways

The gateway enables communication between wireless field devices and host systems connected to an Ethernet, serial, or other existing plant communications network. *Wireless*HART 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 marshalling panels and junction boxes.

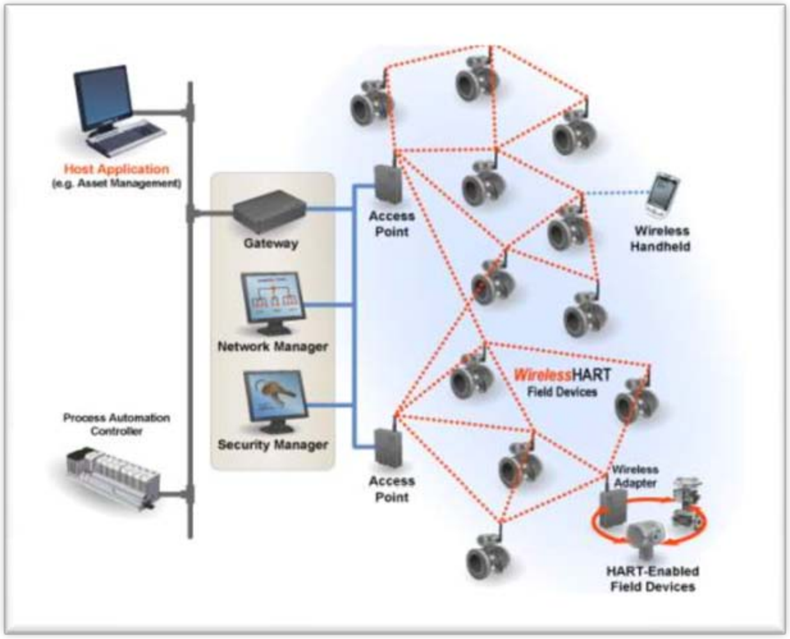


Figure 20: Gateway System Architecture

Below are the requirements for a *Wireless*HART gateway.

- 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 be several

types of DCS, PLC, and data historians requiring multiple protocols. Multiple output protocols allow convenient connectivity with a standard gateway.

- Gateway should support multiple connections and, in effect, act like a server. Typical *Wireless*HART applications require data to be sent to multiple host applications in order to provide data to multiple end users.
- 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 *Wireless*HART devices from multiple vendors.

10.2 Wireless Repeaters

There are no special requirements for a *Wireless*HART repeater. If a repeater is a *Wireless*HART 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 *Wireless*HART device for the specific purpose of acting as a repeater, then that repeating device should be managed like any other *Wireless*HART device and subject to all the specifications of a *Wireless*HART device. *Wireless*HART adapters can be used effectively as repeaters if local power or a wired HART device is available.

10.3 *Wireless*HART Adapters

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

- Access HART diagnostics that are not accessible due to limitations of the host system which may not detect the HART signal on 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 *Wireless*HART signal is used to access parametric and diagnostics data by maintenance or other personnel.
- Act as a wireless repeater.

Below are the *Wireless*HART Adapter specifications.

- Adapter should not affect the 4-20 mA signals under normal operation or in failure mode.
- Adapter should operate like any other *Wireless*HART field device in the *Wireless*HART 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 *Wireless*HART device.

10.4 *Wireless*HART Handheld Communicator

Handheld Communicator is useful

- To carryout device configuration
- To view network diagnostics and health reports.
- To install session keys.

11 Measurements and Choosing *Wireless*HART Device

11.1 Use of *Wireless*HART for Multivariable Process Measurements

*Wireless*HART multivariable transmitter provides benefits like:

1. Lower Installed Cost

   Cost savings because fewer instruments are needed and the numbers of pipe penetrations are reduced.

2. Increased Accuracy

   Achieve accuracy due to single transmitter.

3. Measurement parameters for Multivariable transmitter

   - Differential Pressure
   - Static Pressure
   - Temperature

4. Calculation parameters example for Multivariable transmitter

   - Density Gas Expansion
   - Velocity Discharge Coefficient
   - Viscosity Velocity of Approach
   - Beta Ratio Reynolds Number

5. Parameters available to read at HMI

   - Mass Flow
   - Volumetric Flow
   - Energy Flow
   - Totalized Flow
   - Differential Pressure
   - Static Pressure
   - Temperature

11.2 Use of *Wireless*HART in Various Process Applications

*Wireless*HART devices are available for pressure, flow, level, valve position, pH, conductivity, vibration, temperature, multi-input temperature, acoustic monitoring, Level switches and contact inputs.

1. Safety & Environmental Monitoring
   - Pressure relief and safety valves
   - Monitor safety shower activation
   - Accurately measure emissions
   - Ensure environmental compliance
   - pH monitoring on effluent waste water
   - Rotating Equipment
2. Tough Installation Conditions for Wires/Remote locations
   - Hot
   - Corrosive Atmosphere
   - Wet
3. Movement
   - Rail Cars
   - Skids
   - Flexible Manufacturing
4. Asset Monitoring Applications
   - Bearing & lube temperature
   - Filter differential pressure
   - Vibration monitoring on rotating equipment
   - Surface temperature

12 Host System Requirements

12.1 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 *Wireless*HART gateway should convert data from the *Wireless*HART field network into the desired protocol and physical layer needed for integration into the host system.

12.2 Wireless Host System

Data from *Wireless*HART 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 *Wireless*HART, **Figure 21** shows one possible way the gateway can be integrated into the application, in this case a historian, for the automated collection of data.

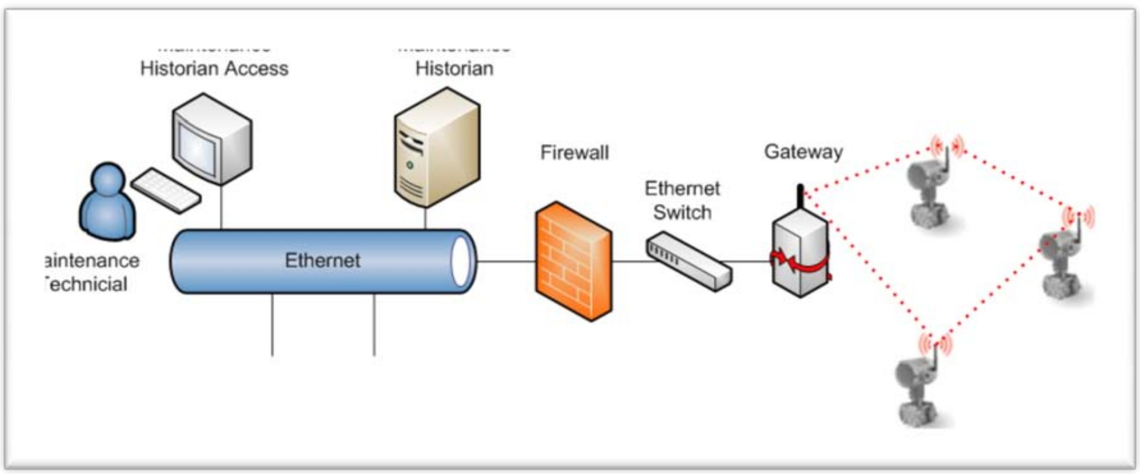


Figure 21: Gateway Integration into Host System

For *Wireless*HART 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, *Wireless*HART provides the missing piece to automation.

For long term scalability, where there may be 1000's to 10,000's of *Wireless*HART 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 *Wireless*HART network resources.

One architecture to consider is a centralized historian and centralized asset management program shown in Figure 22. In this scenario, multiple gateways are connected on the same Ethernet network and server. The data from multiple *Wireless*HART networks is sent to a centralized historian who can then be connected to the applications for each of the end users. In this way, host system resources can be shared, all *Wireless*HART instruments can report to the same asset management solution, uniform security policies *can* be enforced, and end users can see *Wireless*HART data in applications specific to their roles.

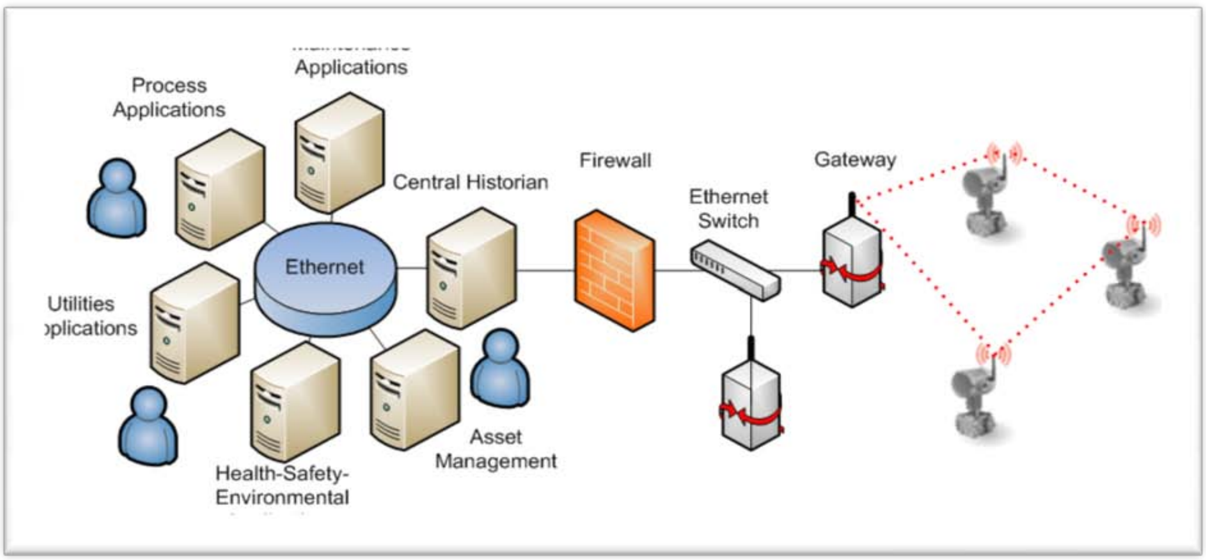


Figure 22: Gateway Information Integrated Into Many Applications

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 *Wireless*HART device is introduced to the plant, host system and integration issues do not need to be solved again and again.

*Wireless*HART is truly scalable; *Wireless*HART 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 *Wireless*HART device can be connected in minutes, configured in minutes, and integrated in minutes if a host system strategy is in place.

12.3 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. *Wireless*HART gateways should support multiple connections into multiple host systems over multiple protocols. This enables *Wireless*HART 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 *Wireless*HART 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 *Wireless*HART 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 *Wireless*HART networks would transition to the new host system (see Figure 23 for an example transitional architecture).

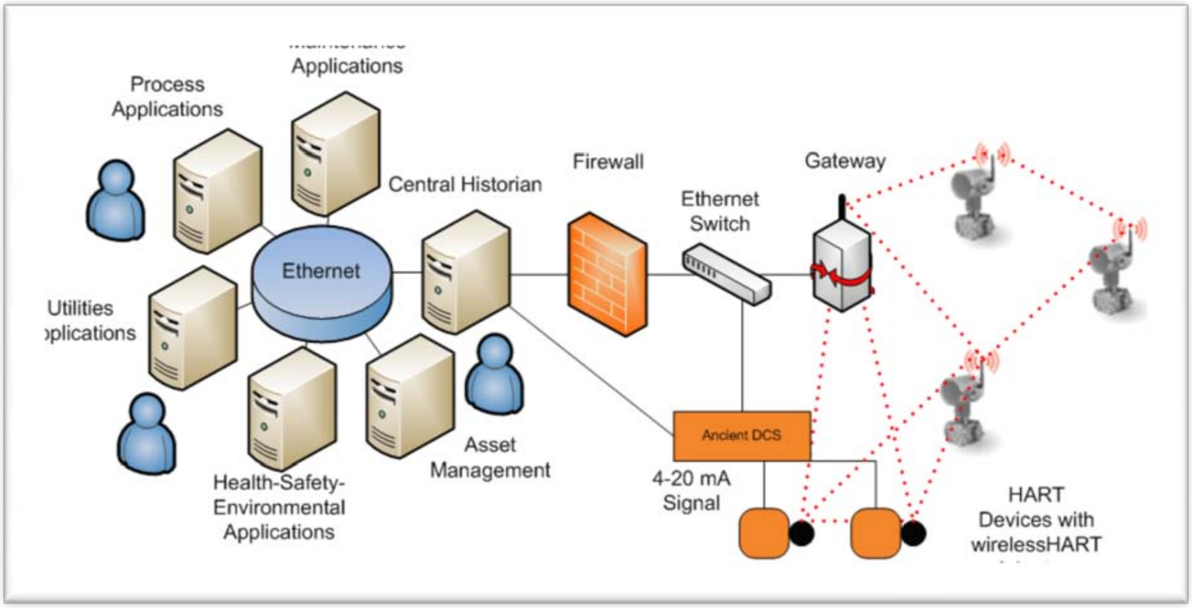


Figure 23: *Wireless*HART Gateway to Bridge Information from Non-HART Host

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 *Wireless*HART data into the host system.
- Potential physical connection points for *Wireless*HART gateways.

12.4 Interoperability

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

12.5 Host System Support for *Wireless*HART Functionality

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

12.6 Device Descriptions Files (DD)

Host system, asset management system, or a handheld field communicator to communicate with a device needs to know the type of data exchange that takes place between host and device. It is also essential to know how to represent it on the user interface. DD file for the device provides this function.

***Wireless*HART DD files can be downloaded from:**

HCF link http://www.hartcommproduct.com/inventory2/index.php?action=list

12.7 Configuration Tools

*Wireless*HART 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 *Wireless*HART devices connected to the gateway.

12.8 Control System Graphics

Not all data collected from the *Wireless*HART 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 *Wireless*HART 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 *Wireless*HART network and dissemination to proper end-users. Many end users are not typically receptive of the benefits of automation and have application specific databases into which data is manually collected and uploaded. With the ability to integrate *Wireless*HART data using standard interface protocols, these existing end-user specific databases can be automatically populated.

12.9 Node Addressing and Naming Conventions

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

12.10 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. For more details refer to section 6.14 Alarm Recommendations for Process Plant

12.11 Maintenance Station and Asset Monitoring

*Wireless*HART 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 *Wireless*HART field device.

The *Wireless*HART gateway should also provide additional diagnostics for network performance. The data from *Wireless*HART 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 *Wireless*HART field device. The gateway can notify the host system if communication problems exist. Additionally, the gateway is responsible for *Wireless*HART network management and network diagnostics.

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

12.12 Historian

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

13 Documenting in Intergraph SPI 2009

*Wireless*HART devices can be fully documented in Intergraph SPI with minimal customization. Below is an example of how to document *Wireless*HART 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.

13.1 User Defined Fields

The first step is to create user defined fields that allow for the accounting of *Wireless*HART 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:

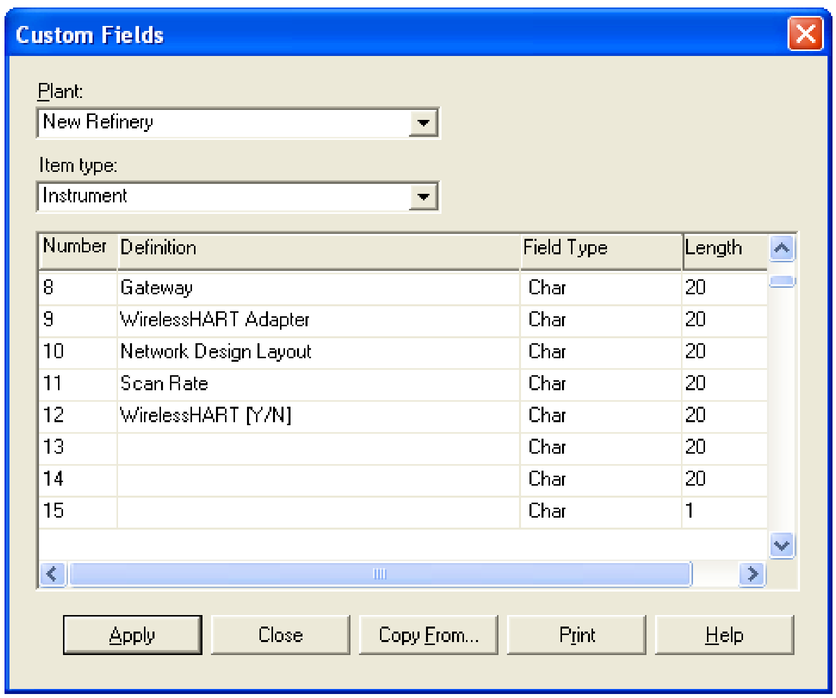


Figure 24: SPI User Defined Fields (UDF) For *Wireless*HART

Type refers to the type of value that can be entered for the value of the UDF. In the case of all the *Wireless*HART 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

Table 13-1: Definitions for *Wireless*HART SPI User Defined Fields below is the explanation of field details.

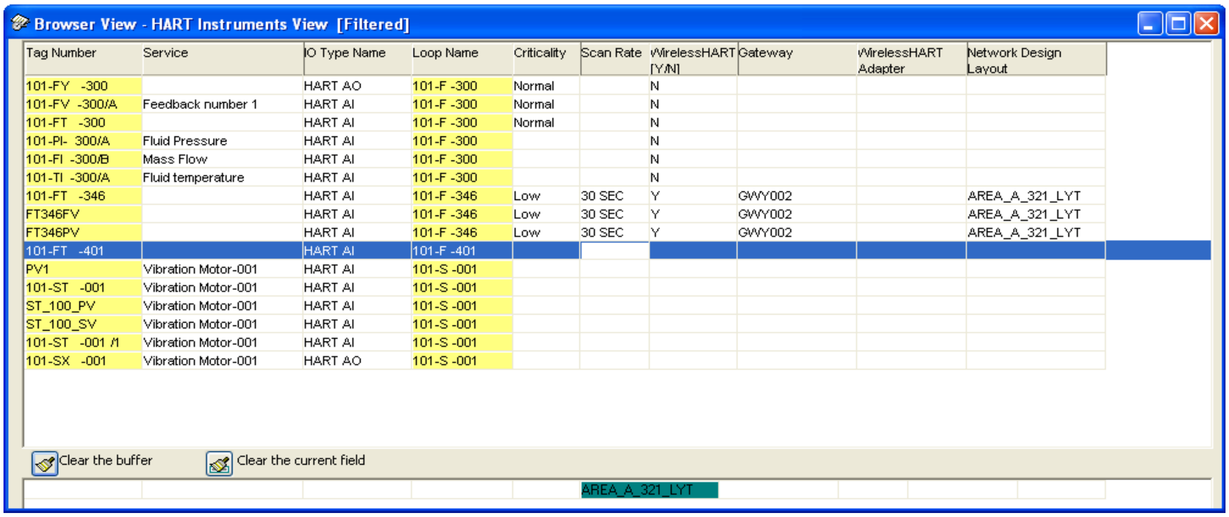
User Defined Field (UDF)	Field Type Example	Purpose
*Wireless*HART (Y/N)	Char Y	Identify a point as wireless at a high level. Will be used for quickly applying design guidelines to determine what is and what is not wireless.
Update rate	Char 1,2, 4, 8, 16,32,64+	*Wireless*HART devices will not all scan at 1 second like wired HART devices. This value will be important for determining what devices may be *Wireless*HART as well as setting configuration parameters.
Gateway	Char GWY002	Defines which gateway a *Wireless*HART device is to be associated.
*Wireless*HART adapter	Char WHA001	Defines which *Wireless*HART adapter a wired HART device is associated with if a device does not have integrated *Wireless*HART 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.

Table 13-1: Definitions for *Wireless*HART SPI User Defined Fields

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 *Wireless*HART. This minimizes exposure to non-pertinent information for non- *Wireless*HART devices.

13.2 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.



Browser View - HART Instruments View [Filtered]

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 /1	Vibration Motor-001	HART AI	101-S -001						
101-SX -001	Vibration Motor-001	HART AO	101-S -001						

Clear the buffer Clear the current field

AREA_A_321_LYT

Figure 25: Custom View Of SPI's *Wireless*HART User Defined Fields

The "Criticality" and "Update rate" should be the foundations for any engineering guidelines that determine whether a device is *Wireless*HART. Some low criticality loops may have update rates faster than 4 seconds, and should be included with the design guidelines. Because *Wireless*HART devices primarily run on batteries, *Wireless*HART 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 *Wireless*HART. 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 *Wireless*HART adapter, then the "*Wireless*HART Adapter" tag information should be defined.

Every *Wireless*HART 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.

13.3 Creating Instrument Types

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

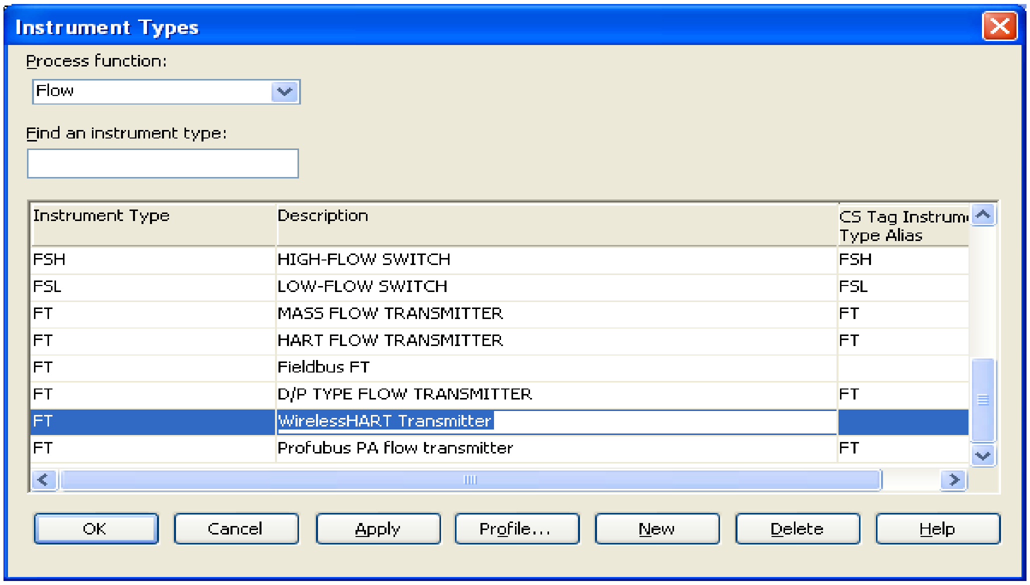


Figure 26: Defining *Wireless*HART Instrument Type In SPI

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

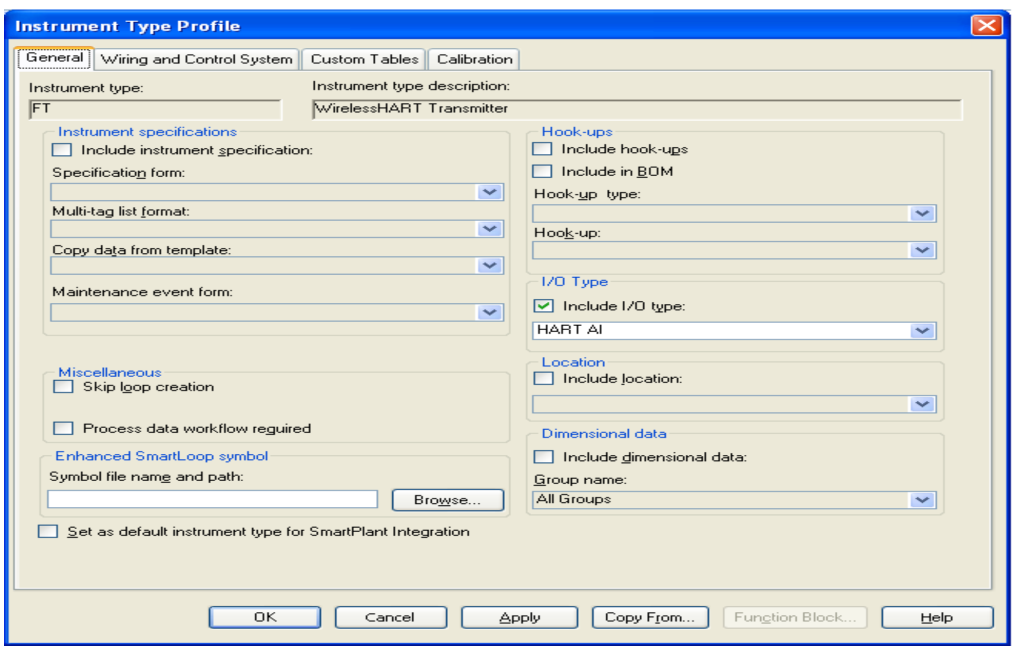


Figure 27: Defining A New *Wireless*HART Instrument In SPI

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 *Wireless*HART is based on HART allows leverage these pre-defined variables.

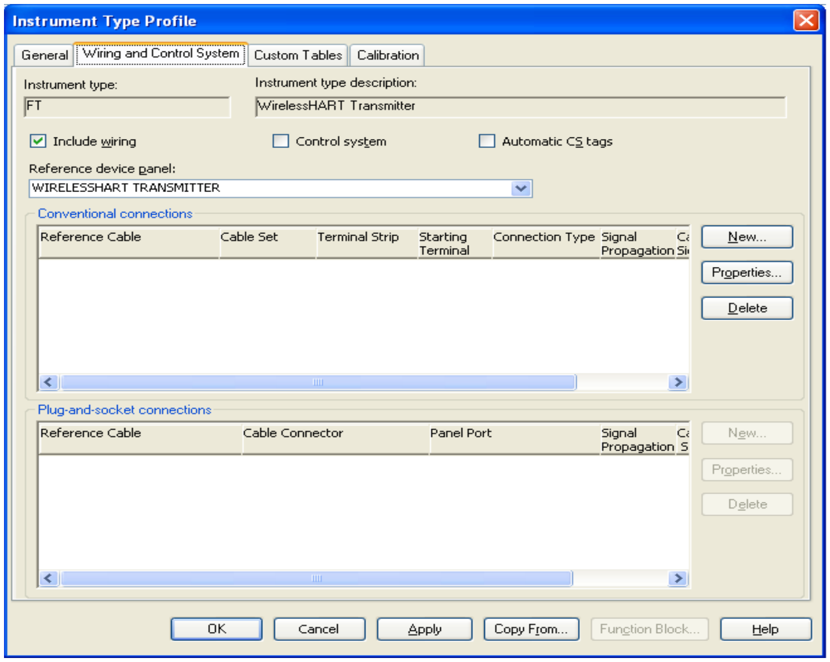


Figure 28: Defining Wiring Types In SPI

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 *Wireless*HART adapters in series with the loop and line power for *Wireless*HART devices. This process should be repeated for each unique *Wireless*HART instrument type.

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

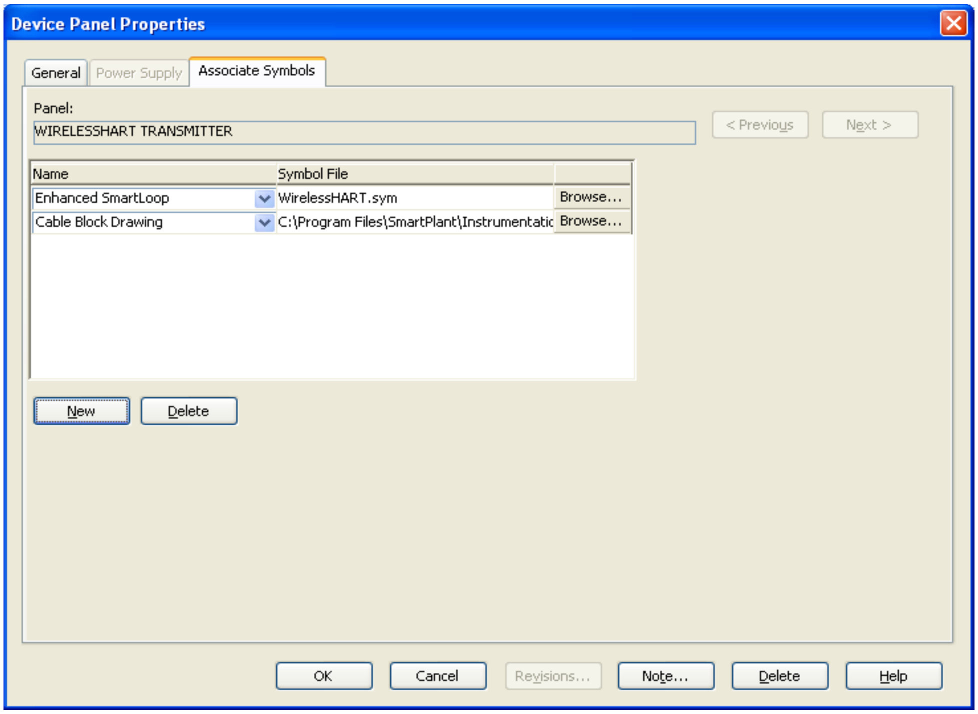


Figure 29: Assigning Symbols In SPI

Basic symbols can be created in SPI using the editing tools. Below are examples for *Wireless*HART field devices and a *Wireless*HART gateway. The zig-zig symbol shown below is defined by ISA. For more documentation, nothing special is required since signalling 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.

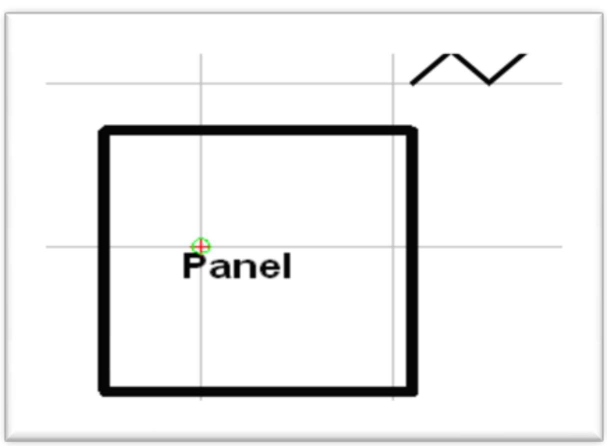


Figure 30: *Wireless*HART Gateway symbol

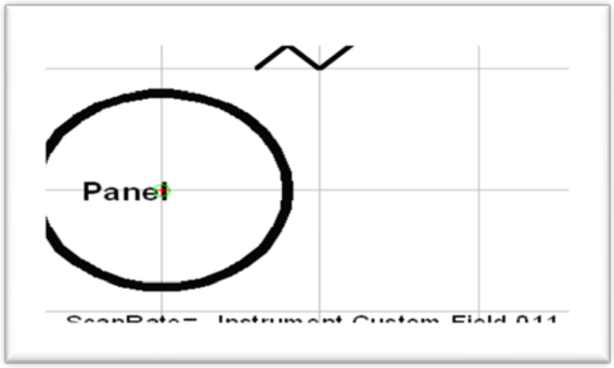


Figure 31: *Wireless*HART Device Symbol

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

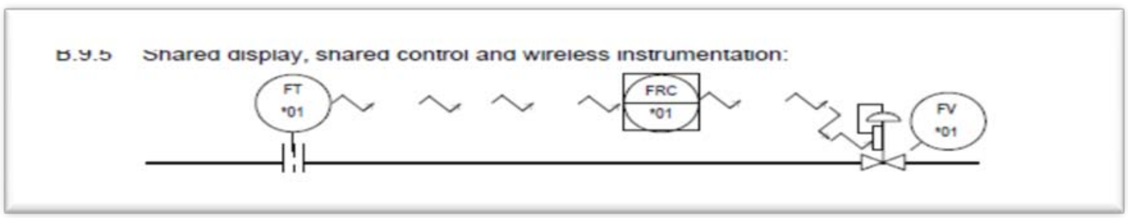


Figure 32: ISA 5.1 Drawing Example

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 *Wireless*HART.

13.4 Loop Drawings

Given that *Wireless*HART 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 *Wireless*HART User Defined Fields. This way, it is very clear to see which wireless devices are associated to which *Wireless*HART 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 *Wireless*HART User defined Fields. .

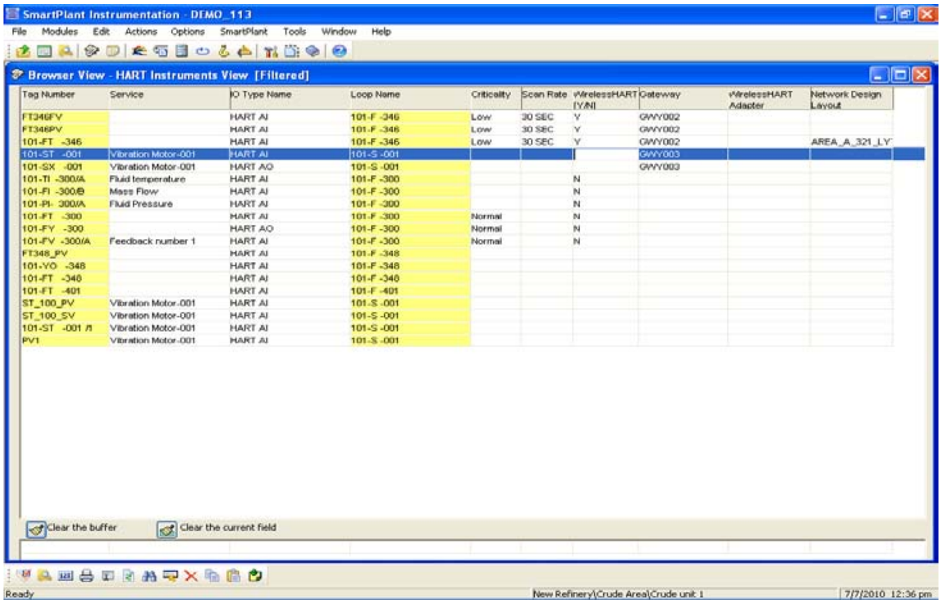


Figure 33: Filtered View Of *Wireless*HART Tags

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.

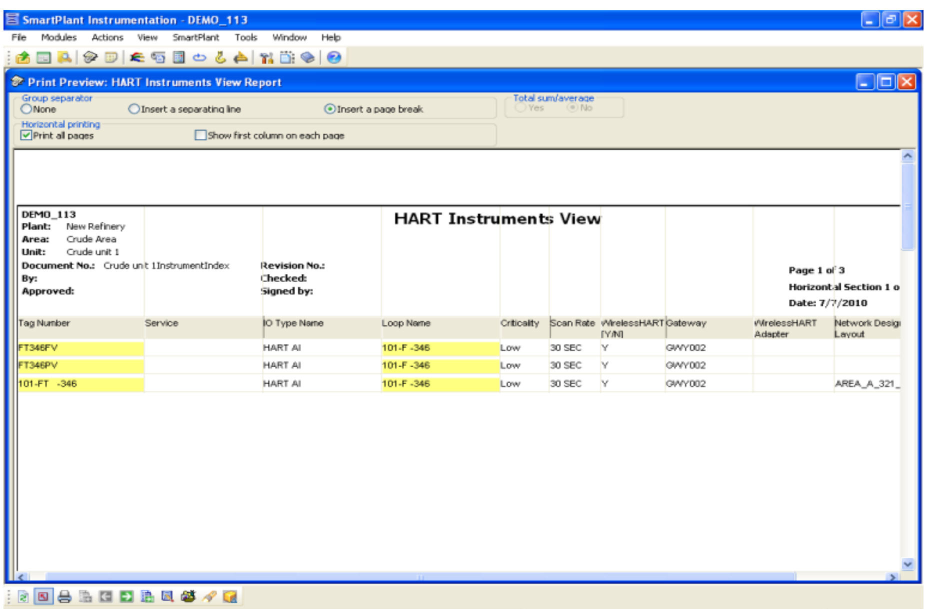


Figure 34: Tag View Filtered By Gateway

Loop Drawings for *Wireless*HART Adapters

A *Wireless*HART adapter is an accessory to a loop and should be treated as a loop accessory like a multiplex 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 *Wireless*HART adapter.

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

Gateway Cable Block Drawings

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

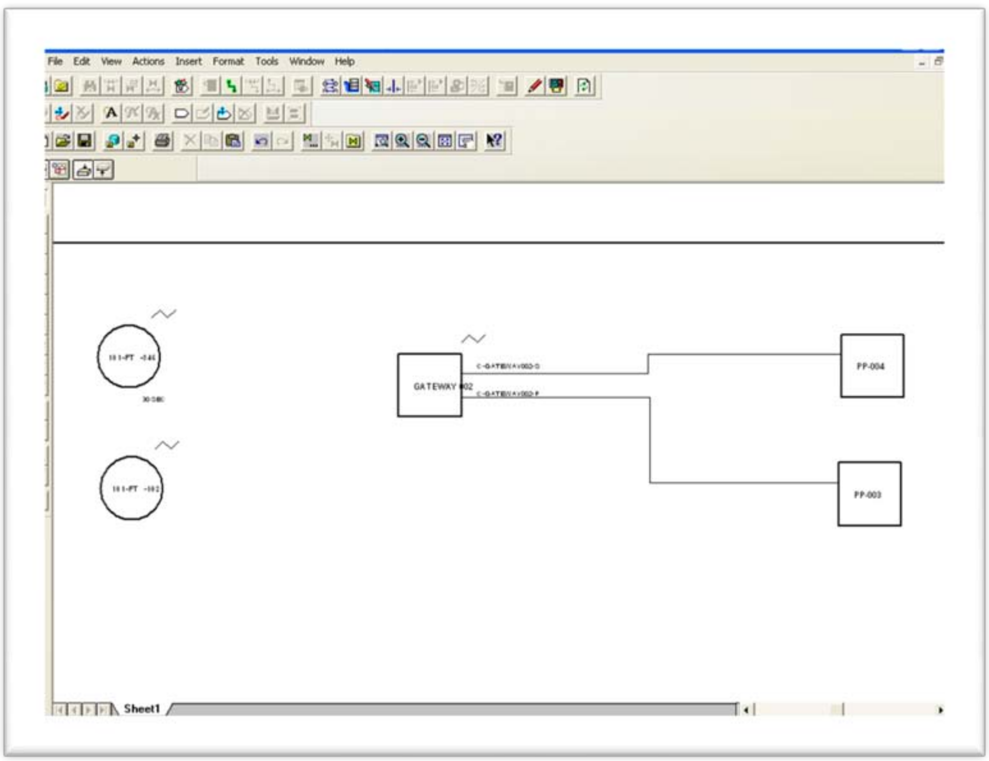


Figure 35: Gateway Cable Block Diagram

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.

Following

Table 13-2: *Wireless*HART Configuration Parameters *Wireless*HART Configuation Parameters.

Specification Field	Typical Value
Update rate	4, 8, 16, 32, 64+
Power Supply	Intrinsically safe, field replaceable battery
Communication Type	*Wireless*HART

Table 13-2: *Wireless*HART Configuration Parameters

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

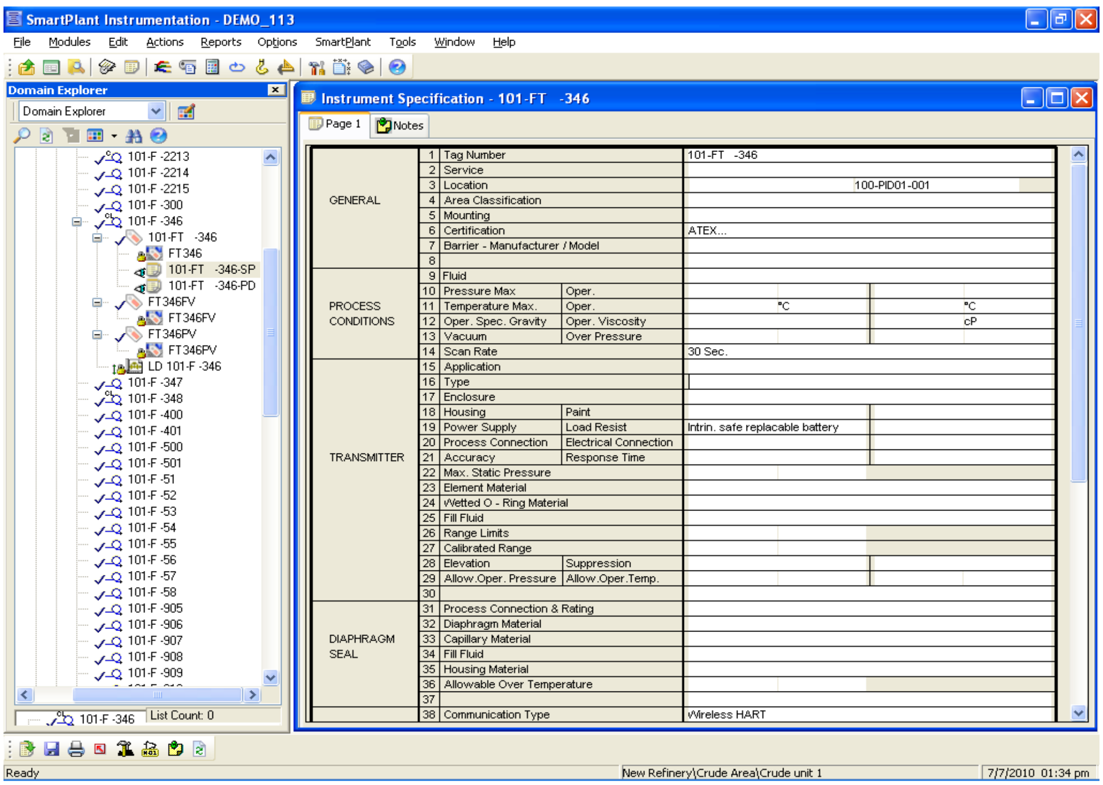


Figure 36: *Wireless*HART Instrument Specification Sheet

13.5 Drawings in SPL – Smart Plant Layout

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

*Wireless*HART gateways should be located like per the network design guidelines.

13.6 Documenting Security Information

The *Wireless*HART 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 *Wireless*HART device with the *Wireless*HART gateway tags. Separately, secure documents containing *Wireless*HART security provisioning including the *Wireless*HART 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 *Wireless*HART field network. This type of security management is similar to the management of security information for control systems and servers.

Appendix A. Example ISA Specifications

Below is a sample specification for a *Wireless*HART gateway.

RECEIVER INSTRUMENTS (Wireless Gateway)

NO	BY	DATE	REVISION

SHEET ___ OF ___ | SPEC. NO. | REV. | CONTRACT | DATE | REQ. P.O. | BY | CHK'D | APPR.

	1	Tag No.	Service
GENERAL	2	Function	Record ☐ Indicate ☐ Control ☐ Blind ☐ Integ ☐ Deviation ☐ Other IEC 62591 wirelessHART Network Administration/Setup
	3	Case	MFR STD ☒ Nom Size 229mmX283mm Color: MFR STD ☒ Other Blue
	4	Mounting	Flush ☐ Surface ☐ Rack ☐ Multi-Case ☐ Other Field mounted with or without remote antenna For Multiple Case, See Spec. Sheet
	5	Enclosure Class	General Purpose ☐ Weather Proof ☒ Explosion-Proof ☐ Class Class I Div II For Use in Intrinsically Safe System. ☐ Other IEC 62591 wirelessHART field Network
	6	Power Supply	117 V 60Hz ☐ Other ac ___ dc ☒ 24 Volts
	7	Chart	Strip ☐ Roll ☐ Fold ☐ Circular ___ Time Marks ___ Range ___ Number ___
	8	Chart Drive	Speed ___ Power ___
	9	Scales	Type ___ Range 1 ___ 2 ___ 3 ___ 4 ___
CONTROLLER	10	Control Modes	P = Prop (Gain), I = Integral (Auto Reset), D = Derivative (Rate), Sub: s = Slow, f = Fast P ☐ PI ☐ PD ☐ PID ☐ I_f ☐ D_f ☐ I_s ☐ D_s ☐ Other ___
	11	Action	On Meas. Increase Output: Increases ☒ Decreases ☐
	12	Auto-Man Switch	None ☐ MFR STD ☐ Other ___
	13	Set Point Adj.	Manual ☐ External ☐ Remote ☐ Other ___
	14	Manual Reg	None ☒ MFR STD ☐ Other ___
	15	Output	4-20 mA ☐ 10-50 mA ☐ 21-103 kPa (3-15 psig) ☒ Other OPC, Modbus RTU, Modbus TCP, HART, HTML
INPUTS	16	Input Signals	4-20 mA ☐ 10-50 mA ☐ 21-103 kPa (3-15 psig) ☐ Other IEC 62591 wirelessHART
	17	No. of Inputs	1 ☐ 2 ☐ 3 ☐ 4 ☐ X 100 devices
	18	Power for XMTRS	External ☒ This Inst ☐ No. of Independent Supplies ___ For Transmitters, See Spec Sheet.
ALARMS	19	Alarm Switches	Quantity ___ Form ___ Rating ___
	20	Function	Meas. Var. ☐ Deviation ☐ Contacts To ___ On Meas ___ Other ___
	21	Options	Filter-Reg ☐ Supply Gage ☐ Charts ☐ Int. Illumination ☐ 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.

ISA Form S20.1a

Figure 37: ISA Sample Wireless Gateway Specification Sheet

Appendix B. *Wireless*HART vs. HART Comparison

Below is a comprehensive list of all differences of end user significance in a *Wireless*HART device relative to a wired HART device. Not all features are implemented in every wireless field device by every vendor.

wirelessHART Parameter	Parameter Options	Example	Technical Details	Notes
Long Tag	field	UNIT_A_TT-101	32 Characters - characters can be any in ISO Latin-1 (ISO 8859-1) character set.	Not unique to wirelessHART - wired HART6 and 7 devices also have Long Tag. Additional field to the HART short tag with 8 characters. Devices can have a long and short tag.
Network ID	Number	10145	An integer number between 0 and 36863	Every gateway must have a unique ID - and field devices must have the matching ID to a specific gateway that it is to join with.
Network Join Key	4 fields	23adfe00-0edf000a-000df038-2398dc07	4 four byte numeric fields (in Hexadecimal format). For example - 4 8 character fields where each character must be a number from 0-9, or a letter from A to F.	Randomize for greatest strength
Broadcast Message	One or more Enumerated choices	Device Status & All Process Variables	Choices include: 1- Primary variable only 2 -Primary variable in percent of range and mA 3 -All dynamic variables in engineering units 9 - Selectable process variables/status in engineering units 33 -Selectable process variables in engineering units 48 -Device status number between 0 and 65535 - Custom command	Not unique to wirelessHART - wired HART devices can also broadcast (burst) commands on the wired loop. Field devices have more than 1 broadcast message available. All wirelssHART devices must support a minimum of 3 messages - but can support up to 250 if they choose. The most optimal configuration to preserve power is to have as few of these broadcast messages configured as possible. We attempt to simplify this by asking the user to choose between 2 options which dictate the complete set of Broadcast messages and Broadcast modes. These 2 options are "Emerson Optimized" or "Generic". Some products (e.g. the THUM Adapter) may have special situations where a simple choice between these 2 global modes are not adequate - and thus multiple broadcast messages should be specified.
Broadcast Variables	One or more sets of 8 Enumerated choices	PV, SV, TV, QV, Variable 0, Variable 1, Variable 2, and Variable 3	Choices include: 243 - Battery Life 244 - Percent of range 245 - Loop Current 246 - PV 247 - SV 248 - TV 249 - QV 250 - Disabled 0 thru 249 specific to each device User-friendly choice names from 0 to 249 are device specific. Might just have to specify numbers	Not unique to wirelessHART - wired HART devices can also broadcast (burst) commands on the wired loop. Field devices have 1 set of broadcast variables for each broadcast message. Broadcast variables are only applicable when the corresponding broadcast message is Selectable process variables / status (up to 8 can be chosen), or Selectable process variables (up to 4 can be chosen).
Triggered Broadcast Rate	One or more Numbers	60	In seconds - must be 1, 2, 4, 8, 16, 32, or any number between and including 60 to 3600 seconds)	Not unique to wirelessHART - wired HART 7 devices can also broadcast (burst) commands on the wired loop. Field devices have 1 broadcast rate for each broadcast message. We attempt to simplify this by asking for ony 1 broadcast rate, and setting all available broadcast messages to the same rate. Some products (e.g. the THUM Adapter) may have special situations where multiple rates should be specified.
Broadcast Mode	One or more Enumerated choices	Continuous	Choices include: Disabled Continuous Report by Exception On Change	Not unique to wirelessHART - wired HART 7 devices can also broadcast (burst) commands on the wired loop. Field devices have 1 Broadcast Mode for each broadcast message. Most products only support Disabled or Continuous. Future revisions of products will offer the remaining 2 modes.
Maximum Broadcast Rate	One or more Numbers	60	In seconds - must be 1, 2, 4, 8, 16, 32, or any number between and including 60 to 3600 seconds) Must be larger than Triggered Broadcast rate.	Not unique to wirelessHART - wired HART 7 devices can also broadcast (burst) commands on the wired loop. Field devices have 1 Maximum broadcast rate for each broadcast message. This parameter is only applicable when the corresponding Broadcast mode is set to "Report by Exception" or "On Change".
Broadcast Trigger Threshold	One or more Number	345.2	IEEE-754 single precision floating point value	Not unique to wirelessHART - wired HART 7 devices can also broadcast (burst) commands on the wired loop. Field devices have 1 Burst Trigger Threshold for each broadcast message. This parameter is only applicable when the corresponding Broadcast mode is set to "Report by Exception".
Broadcast Trigger Units	One or more Fields	PSI	Choices include all units available in the HART Common Tables Specification.	Not unique to wirelessHART - wired HART 7 devices can also broadcast (burst) commands on the wired loop. Field devices have 1 Burst Trigger Units for each broadcast message. This parameter is only applicable when the corresponding Broadcast mode is set to "Report by Exception".
Event Notification Control	One or more enumerated choices	Disabled	Choices include: Enabled Disabled	Not unique to wirelessHART - wired HART 7 devices can also broadcast (burst) events on the wired loop. Field devices have 1 Event Notification Mode for each event. All WirelessHART devices must support at least 1 event - but can suport up to 250 events if they choose.
Event Notification Retry Rate	One or more Numbers	60	In seconds - must be 1, 2, 4, 8, 16, 32, or any number between and including 60 to 3600 seconds)	Not unique to wirelessHART - wired HART 7 devices can also broadcast (burst) events on the wired loop. Field devices have 1 Event Notification Retry Rate for each event.
Event Notification Default Rate	One or more Numbers		In seconds - must be 1, 2, 4, 8, 16, 32, or any number between and including 60 to 3600 seconds) Must be greater than Event Notification Retry Rate	Not unique to wirelessHART - wired HART 7 devices can also broadcast (burst) events on the wired loop. Field devices have 1 Event Notification Default Rate for each event.
Event Notification Debounce Rate	One or more Numbers		In seconds - must be 1, 2, 4, 8, 16, 32, or any number between and including 60 to 3600 seconds) Must be less than Event Notification Retry Rate	Not unique to wirelessHART - wired HART 7 devices can also broadcast (burst) events on the wired loop. Field devices have 1 Event Notification Debounce Rate for each event. All WirelessHART devices must support at least 1 event - but can suport up to 250 events if they choose.
Event Notification Event Mask	One or more sets of 13 integers	0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF		Not unique to wirelessHART - wired HART 7 devices can also broadcast (burst) events on the wired loop. Field devices have 1 set of Event Notification Masks for each event. All WirelessHART devices must support at least 1 event - but can suport up to 250 events if they choose.
Power Source	Field	Battery	Choices include: Battery Energy Scavenging Line Power	Most devices only support Battery as a choice. Future products may allow one or more of the other choices.
Radio Output Power	Field	+10dBm	A signed integer between +10 and -10.	Whole wirelessHART network should be set to same value. Most wireless products to dat support either +10 or 0 dBM only.

Figure 38: *Wireless*HART vs. HART Comparison

Appendix C. Design Resources

*Wireless*HART vendors develop network design tools to support:

- Network Design
- Gateway Capacity Planning
- Battery Life Estimation by Device Type

Below are known network design tools. Contact your *Wireless*HART vendor for more information.

Emerson Process Management

- **Wireless Planning Tool -** With the Wireless Planning Tool, user can upload an aerial image of plant (or a segment of your facility) and design a wireless network. Tool checks the Wireless network against industry best practices.
- **AMS Wireless SNAP-ON** – Is an automated tool for designing and testing network design that can also monitor networks after installation.
  - o http://www2.emersonprocess.com/siteadmincenter/PM%20Asset%20Optimization%20Documents/ProductDataSheets/amsdm_ds_wirelesssnapon.pdf
- **Emerson Power Module Life Estimator** – Provides estimates for battery life by wireless device type and factors in update rate and environmental variables.
  - o http://www3.emersonprocess.com/rosemount/PowerModuleLifeCalculator/Default.aspx
- **Emerson Smart Wireless Estimator** – Provides estimated cost and time saving comparisons for wired verses wireless automation.
  - o http://www3.emersonprocess.com/rosemount/wirelessestimator/default.aspx
  - o **Emerson Smart Wireless Tools and Resources** – Current and future tools and resources can be found on the following website: http://www2.emersonprocess.com/en-us/plantweb/wireless/Pages/WirelessHomePage-Flash.aspx

Appendix D. 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.

*Wireless*HART 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. *Wireless*HART 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 *Wireless*HART vendor. Since vendors for multiple applications can use the same spectrum, *Wireless*HART must be able to successfully coexist.

*Wireless*HART uses multiple techniques to coexist with other wireless applications:

- Network segmentation – allows thousands of *Wireless*HART 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 – *Wireless*HART devices are very low power relative to handheld personnel communicators, Wi-Fi, and RFID readers. This helps prevent *Wireless*HART 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 *Wireless*HART devices self-organize paths through the process environment that mitigate RF obstacles the same way as physical obstacles.

- Channel hopping – *Wireless*HART 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. *Wireless*HART 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 have 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.

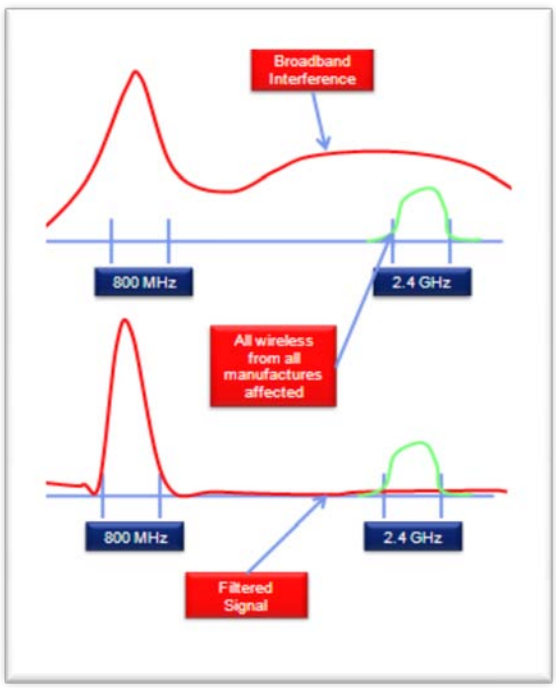


Figure 39. Installing a Low-Pass Filter

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 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, 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 *Wireless*HART networks.
  - Every network in the process facility should have a unique Network ID and Join Keys.
  - *Wireless*HART 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.

Appendix E. References

Topic	Reference
*Wireless*HART	HART Communication Foundation http://www.hartcomm.org/protocol/wihart/wireless_technology.html - Protocol Specifications, Overview, Member Companies. *Wireless*HART: 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 *Wireless*HART.
Security	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 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) 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) DOE – "21 Steps to Improve Cyber Security of SCADA Networks" (an oldie but a goodie) http://www.oe.netl.doe.gov/docs/prepare/21stepsbooklet.pdf Emerson – "DeltaV System Cyber-Security" http://www2.emersonprocess.com/siteadmincenter/PM%20DeltaV%20Documents/Whitepapers/WP_DeltaVSystemSecurity.pdf 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 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 NIST – SP 800-53, Revision 3 "Recommended Security Controls for Federal Information Systems and Organizations" (this latest version includes Appendix I: Industrial Control Systems, Security Controls, Enhancements, and Supplemental Guidance) http://csrc.nist.gov/publications/nistpubs/800-53-Rev3/sp800-53-rev3-final.pdf NSA – "Defence 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 Defence: Consensus Audit Guidelines" (note link to printer friendly version) http://www.sans.org/cag/

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