HART COMMUNICATION FOUNDATION

TECH NOTE

Wireless Introduction

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Contributors: Gerrit Lohmann – Pepperl+Fuchs GmbH

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Attention: Foundation Director
HART Communication Foundation
9390 Research Boulevard, Suite I-350
Austin, TX 78759, USA
Voice: (512) 794-0369
FAX: (512) 794-3904
http://www.hartcomm.org

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Introduction

Wireless communication is emerging from the office world to the industrial world. Since industrial communication underlies stronger conditions than office communication, some know-how is important for users who apply wireless communication in industrial environments.

This document will introduce to

- RF and radio basic terminology
- Boundary Conditions for RF in industrial environment
- Modern Radio technology and standards
- Media Access and Networking
- Conditions for using wireless technologies in industrial applications

Radio Frequency

The radio waves are part of the electromagnetic spectrum, covering several other parts of radiation like light, gamma rays etc.

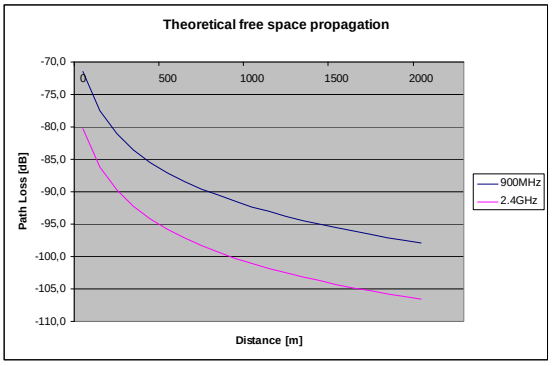
Therefore, the propagation of radio waves can generally be compared with the propagation of light. Light moves straight through space and can

- Penetrate material (glass)
- Be damped (either through material like fog or by simply by distance)
- Be reflected (on mirrors)
- Be absorbed

Radio waves also can penetrate material, be reflected or absorbed.

- Due to the other frequency (radio waves are of much lower frequency of light), the penetration of material is better. Radio waves can even penetrate walls if not too massive
- Radio waves are damped by the material and by distance
- Radio waves will be absorbed by massive material and do not penetrate them anymore
- they are reflected on the ground or obstacles

Generally, in an open space, the propagation goes undisturbed straight in all directions and is only damped by distance.

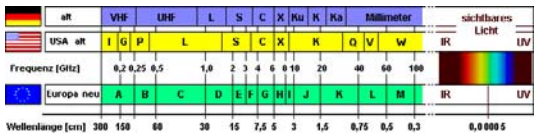


The damping is described in dB

Radio Technology

To enable the receiver and sender of the information to communicate, both have to agree on what frequency they send. This frequency will be in one of the bands reserved for radio communications. The bands are regulated by official agencies and the usage of these bands is therefore restricted. In most bands, a license must be obtained to allow usage of it. The regulations are different from country to country.

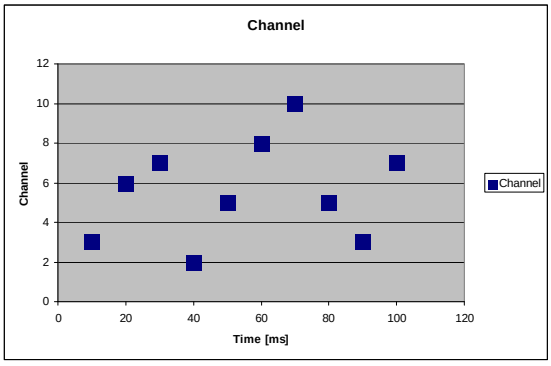
The exceptions for licensed usage are ISM bands (Industrial, scientific, medical). In these bands anyone is allowed to send and receive, following some restriction like sending power. The only worldwide usable band for ISM is 2.4GHz



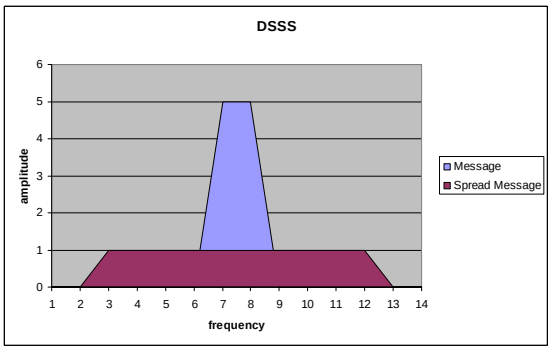
Now, in this band single channels are established. This can either be a single frequency (like 2.45GHz) or a frequency range, e.g. 2.407 to 2.447 GHz. This is a difference of 40MHz. This range is called bandwidth. As higher the bandwidth, as more data can be transmitted.

Using the higher bandwidth, one speaks also of spectrum usage. Spectrum usage can either be in sequence like FHSS, or simultaneously as.

FSSS uses a single frequency at a time and another frequency during the following transmission. So, the whole spectrum is used, but not for one transmission but for consecutive. Since the sequence of the single channels is unknown, it is hard to tap these transmissions and due to the short peaks of transmissions, the disturbance of other radio systems is reduced.



DSSS in contrary uses the entire frequency spectrum during one transmission. Therefore, the sending power can be reduced, the signal is hidden in the background noise and cannot be tapped nor jammed nor it is jamming other radio transmissions



The sending power is one restriction in the ISM band of 2.4GHz. It is only allowed to send with an output power of 10mW, in some countries or regions it is allowed to send with 100mW. As more sending power is allowed, as longer the possible range is.

The sending power is sometimes also describes as dB in relation to EIRP. EIRP means @. An isotropic radiator radiates equally in all directions (like the sun). But real world antennas radiate in a different pattern, e.g. a donut like shape. So the power is not wasted to the top and bottom but more in the horizontal surface. So the 10mW are not distributed equally, but or focused which increases the sending power of e.g. 2dB (in relation to the 10mW)

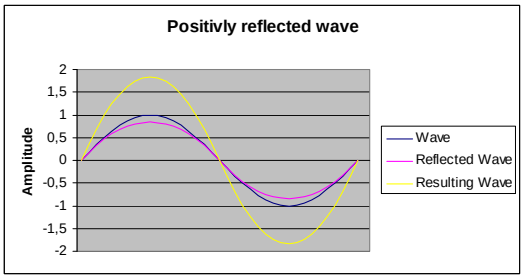
Another factor for the range is the receiver sensitivity. Even if the sending power is restricted, the sensitivity is not. So as better the receiving sensitivity is, as longer the range which can be obtained.

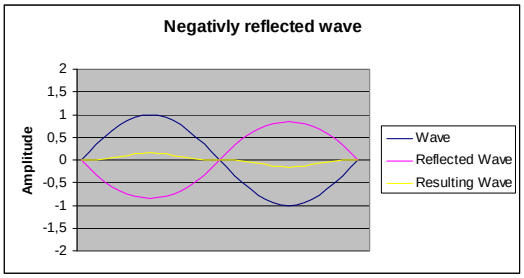
Boundery Conditions for RF in industrial communication

The general properties of radio frequency do of course also apply in industrial environment. Three main effects have to be taken into account in industrial environments

- Interference
- Moving equipment and people
- Multipath fading

Interference happens wherever a wave is reflected or is superimposed by another wave. This can either have a positive effect or a negative effect:





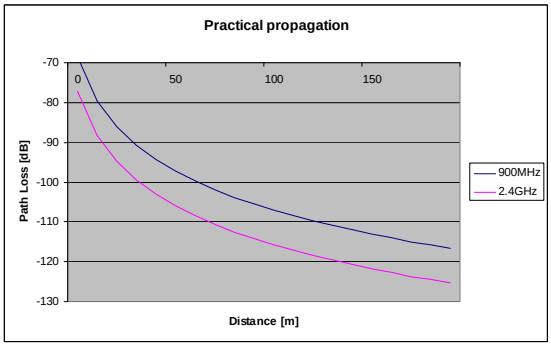
The second effect is that industrial environments are not static but dynamic. Vehicles, moving equipment like tanks, people walking through will change the environment. Therefore, the propagation of radio waves is altered.

The third effect is multipath fading. Due to reflections, one wave is moving on different paths from the sender to the receiver and arrives there then lightly time shifted. This can distort the wave so the receiver does not recognize it anymore.

As result of those three effects two main consequences must be taken into account when applying wireless communications in industrial environments

- Range
- Reliability

The range is decreased compared to the theoretical free space propagation. A practical example for industrial environment is shown below:



The moving equipment and changing environment decreases the reliability of the radio communication. A connection working at one time does not work another because a truck is standing in the way. This decreases the reliability.

Modern Radio Technology and Standards

To enable radio communication, a common standard is mandatory. The standard makes devices of different vendors compatible to each other end enable easy to use technology.

Currently, in the 2.4GHz Band there are three major known standards available. They have been defined by IEEE in the family of communication protocols and are worldwide usable.

- IEEE 802.11 (WiFi)
- IEEE 802.15.1 (Bluetooth)
- IEEE 802.15.4 (ZigBee)

One of the widest used is IEEE802.15.11, commonly known as WLAN or WiFi (even if this is not 100% correct). IEEE802.11 provides a local infrastructure for fast wireless transmission of relative amount of data over some distance like office areas or your home network.

IEEE802.15.1 is known as Bluetooth. This provides a personal area network for cable replacement of auxiliary devices and is able to transmit some less data than WLAN over a very limited range. This is also called WPAN (Wireless Personal Area Network)

IEEE802.15.4 is the basis for Networks like ZigBee, where very limited data is transmitted over a medium distance through a network of knots so the covered area is extended.

Media Access and Networking

All the standards described above have to access the same space: the air. If all participants access this at the same time, collisions of communication will occur. Therefore, the media access must be handled. There are two principles used to coordinate media access

- TDMA (Time Division Multiple Access)
- CSMA (Carrier Sense Multiple Access)

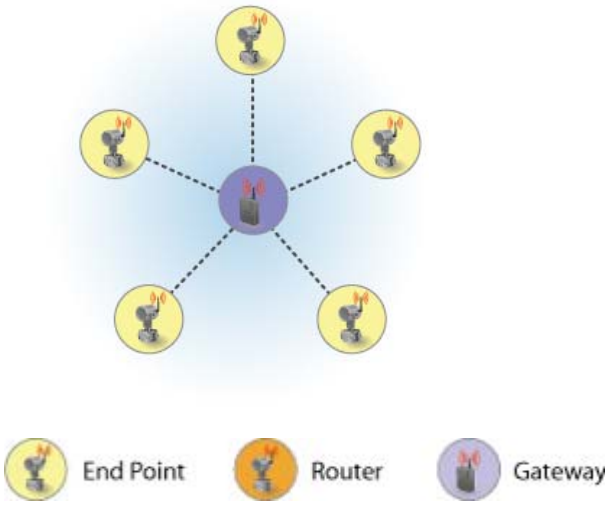
With TDMA, the data are transferred at a given time slot. So all of the participants in a network know the time slot when to send and to receive and avoid collisions with this.

CSMA avoids collisions with random delay times after a free channel is recognized. So if a channel is recognized to be free, every participant waits another random time and it is very unlikely that the next send packages collide.

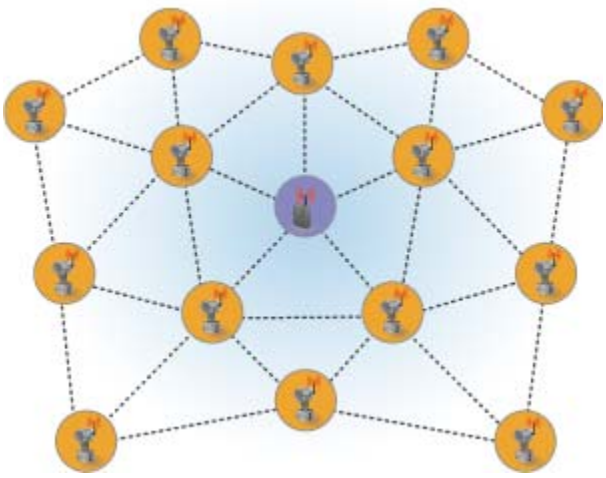
The other thing which is relevant in terms of the standards described above is how the network is organized. There are three basic layouts of networks

- Star
- Mesh
- Star-Mesh or Hybrid

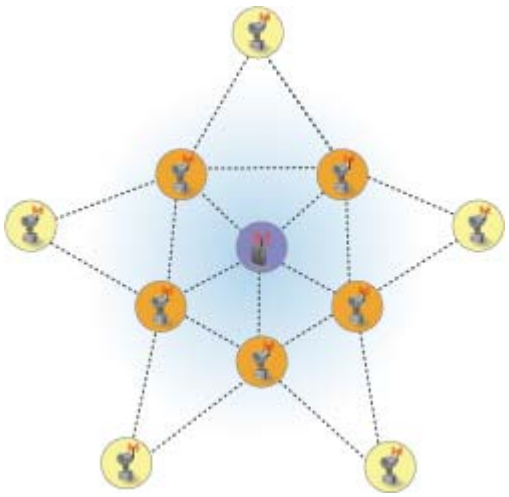
Using star topology, each wireless sensor end point sends data directly to the gateway. From there data is sent on to other systems. Star networks offer the fastest data gathering speed, but all participants must be in the communication range of the gateway. This topology suits installations that need the lowest power consumption over limited geographic range



In mesh networks, each wireless sensor acts as a router, sending and receiving data from other sensors or the gateway. Self configuring networks automatically determine the best path for data to take from sensor to gateway. Data is automatically sent around failed sensor routers. This layout is good for wide area networks with high redundancy, but enough power for all participants is available to route the messages.



Star-mesh networks combine star and mesh topologies to gain the speed of the star network with the self-repairing capability of the mesh network. Sensors may be either end points or routers, depending on where they are used in the system.



Conditions for using wireless technologies in industrial applications

If an office application wireless system looses a package once in a while, it is resend and therefore the loss is not recognized by the user. In contrary to this, Industrial applications rely on secure data transmission. For some use cases compromises can be made, e.g. to parameterize devoices or for asset management applications. But closed control loops rely on a strict data transmission.

The reliability of a data transmission is defined in Bit Error Rate, means how many Bits are not transmitted correctly in a number of Bits. The better the BER, the better the reliability of the data transmission. A wired transmission usually has a BER

To depict the relations, a Profibus has a BER of…@., a wireless system without error correction ….@

So with correction algorithms a better BER is possible, but the algorithm needs time to find out and correct the faulty message. If the message is too disrupted, the message cannot be reconstructed and a resending might be necessary. This delays the data transmission and a closed loop control could get out of phase.

To define the single application, 6 application classes have been defined:

Category	Class	Application	Description
Safety	0	Emergency action	*(always critical)*
Control	1	Closed loop regulatory control	*(often critical)*
	2	Closed loop supervisory control	*(usually non-critical)*
	3	Open loop control	*(human in the loop)*
Monitoring	4	Alerting	*Short-term operational consequence (e.g., event-based maintenance)*
	5	Logging and downloading/uploading	*No immediate operational consequence (e.g., history collection, sequence-of-events, preventive maintenance)*

Summary and Conclusion

Using wireless technologies in industrial application is surely possible, but some restrictions must be considered.

- Radio technology uses a shared medium and does not guarantee transmission reliability as a wire
- Radio waves are damped absorbed and mirrored by obstacles and therefore not everywhere is a connection possible
- License free bands have just limited range, also other wireless systems might make use of the band and cause coexistence issues