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*Technical Report*

**Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD); Part 2: Technical characteristics for SRD equipment for wireless industrial applications using technologies different from Ultra-Wide Band (UWB)**

Reference

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# Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee on Electromagnetic compatibility and Radio spectrum Matters (ERM).

The present document is part 2 of a multipart deliverable covering Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD), as identified below:

Part 1: "Technical characteristics for SRD equipment for wireless factory/industrial applications using ultra-wideband technologies";

**Part 2: "Technical characteristics for SRD equipment for wireless industrial applications using technologies different from Ultra-Wide Band (UWB)".**

# Executive Summary

Industrial automation requires "robust" wireless technologies to be used for their critical wireless links in industrial applications.

The advantages of wireless are beneath savings of often complex and expensive cables, cable protection and plugs, the increased mobility and flexibility as well as the wear and tear free transmission medium. These advantages are particularly high in the area of:

- monitoring and mobile worker communication;
- wireless sensors and actuators at moving parts;
- setups that require flexility in terms of tool or machine reconfigurations.

Different functions can be mastered substantially more efficient by a wireless network of data acquisition terminals, robotic type equipment or automated guided vehicles.

For the sensor and actuator type of applications in industrial automation, the main requirement is the real time behaviour:

- Determinism for process industry.
- Low latency and determinism for factory automation.

Real time means a maximum response time defined by the type of application.
E.g. on the factory floor of discrete manufacturing, very short latencies of a few ms and a very high availability (high robustness) is necessary in order to avoid interruptions in the manufacturing process.

In higher levels of the automation hierarchy e.g. at the control or enterprise level, the data volume rises, so throughput, security and availability becomes more important, but real–time communication requirements decrease.

To meet these requirements, both application categories require specific wireless technologies for specialised sensor/actuator networks in combination with specific spectrum for industrial SRDs. Non-critical links can continue to use the existing spectrum for generic SRDs like those listed in clause 6.1.

Industrial automation equipment are typically designed in a way that it is not interfered by other wireless applications present in the industrial environment. If a critical wireless link of an industrial application would be interrupted (interfered), or not respond instantaneously, safety measures beyond communication take effect immediately, according to EN/IEC 61508 [i.14] (listed under the Machinery Directive) and EN/IEC 61784-3-series [i.15].

To achieve the required performances for different industrial wireless applications, it is important to achieve either short latencies or high throughput, in addition to range and availability, etc. Therefore, industrial users very much depend on the chosen technical solutions for their seamless operational procedures, i.e. a high dependability is envisaged.

In addition, the manufacturing processes require often to use more than one wireless technology simultaneously within the same area or environment.

All the specific needs identified above complicate the selection of frequencies to be used for such applications as availability of the spectrum, and the predictability and efficiency of the communication links is of key importance for the automatic manufacturing process hence why the usual SRD bands are not adequate for these applications.

The intent of the present document is to have spectrum identified and an appropriate regulation developed where these wireless automation devices can operate as intended without being hindered by other applications operating in intensively used SRD bands. This means that, for the industrial applications, frequency bands different from the 2 400 MHz to 2 483,5 MHz band have to be identified as the usage of an adequate spectrum sharing mechanism to be implemented by the equipment, as mandated by the European Commission for using the 2,4 GHz band for power levels above 10 mW, is in conflict with the nature of these applications.

For industrial automation, having the same frequency bands available in different countries/regions across the globe is also a very important aspect and an essential requirement, as in today's global economy, machines or parts of a machine are built and tested (already with a wireless system being part of it) in different countries around the world and then finally assembled in another country. After a model change (e.g. automotive), the production equipment might be sent to yet another country for further production.

As explained above, the focus in industrial automation is on achieving robustness, determinism and predictability for the manufacturing processes. However it is understood that, for the industrial applications using critical wireless links, operation in overcrowded bands like the 2,4 GHz band cannot be achieved. This is caused by the mandatory use of adequate spectrum sharing mechanisms to be implemented by the equipment, as mentioned above.

So while the non-critical links could use existing spectrum and existing ETSI standards, including the 2,4 GHz up to 2,4835 GHz band, new frequencies (outside the 2,4 GHz band) need to be identified for the critical links of industrial applications. The preference is to have this new spectrum close to or adjacent to bands which are globally already available and for which industrial wireless technology has already be developed.

To address the specific needs for wireless industrial applications, the following requirements are identified:

- The use of specific technologies in order to be robust in a dynamic and multi-path environment.
- Frequency bands (and corresponding requirements according to clauses 6, 7 and 8), which are globally available or adjacent to globally available bands as to use existing technology developed for these bands.
- Frequency bands above 1,5 GHz to avoid interferencefrom welding machines and below 6 GHz due to the quasi optical propagation behaviour above and requirement for non-line-of-sight wireless communications.

# Introduction

The present document has been developed to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

The present document describes spectrum and operational key requirements for the wireless industrial applications.

Wireless industrial applications allow further optimization of production processes resulting in lower cost, lower energy consumption, increased productivity and safety, in industrial facilities.

# 1 Scope

The present document describes the technical characteristics and applications specific radio spectrum requirements for SRD equipment in the industrial environment using technologies different from ultra-wide band, which may require a change of the present frequency designation/utilization within the EU or CEPT.

Non-critical wireless links for industrial applications could use existing spectrum regulation and existing ETSI standards, including the 2,4 GHz up to 2,4835 GHz band, however new frequencies (outside the 2,4 GHz band) need to be identified for the critical wireless links of industrial applications. The present document includes the necessary information to support the co-operation between ETSI and the ECC including:

- Market information (see clause 5).
- Technical information including expected sharing and compatibility issues (see clause 6).
- Regulatory issues (see clauses 7 and 8).

NOTE: The 2,4 GHz band is not considered within the present document as existing regulations and standards can be used for these applications.

# 2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

## 2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

## 2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ERC/REC 70-03: "Relating to the use of short range devices (SRD)".

NOTE: Available at: http://www.erodocdb.dk/doks/implement_doc_adm.aspx?docid=1622.

[i.2] ETSI EN 301 489-1 (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements".

[i.3] EN/IEC 61784-2:2010: "Industrial communication networks - Profiles - Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC 8802-3".

[i.4] EN/IEC 62591: "Industrial communication networks - Wireless communication network and communication profiles - WirelessHART®".

NOTE: WirelessHART technology is a registered trademark of the HART Communication Foundation.

[i.5] IEC 62443 (all parts): "Industrial communication networks - Network and system security".

[i.6] IEEE 802.11-1999: "IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access, Control (MAC) and Physical Layer, (PHY) Specifications".

NOTE: Available at: http://www.ieee.org.

[i.7] IEEE 802.15.1-2005: "IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 15.1: Wireless medium access control (MAC) and physical layer (PHY) specifications for wireless personal area networks (WPANs)".

NOTE: Available at: http://www.ieee.org.

[i.8] IEEE 802.15.4: "IEEE Standard for Information technology- Telecommunications and information exchange between systems- Local and metropolitan area networks- Specific requirements Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs)".

NOTE: Publisher: The VDI/VDE Society for Measurement and Automatic Control (VDI/VDE - GMA Gesellschaft Mess- und Automatisierungstechnik); Beuth Verlag, December 2009.

[i.9] NAMUR NE124-2009: "Wireless Automation Requirements".

NOTE: Available at: http://www.namur.de/.

[i.10] NAMUR NE133-2010: "Wireless Sensor Networks: Requirements for the Convergence of existing Standards".

NOTE: Available at http://www.namur.de/.

[i.11] IEC 62657-2: "Industrial communication networks - Wireless communication networks - Part 2: Coexistence management".

NOTE 1: Available at: http://www.iec.ch/.

NOTE 2: To be published.

[i.12] ERC Recommendation 74-01: "European Radiocommunications Committee (ERC) within the European Conference of Postal and Telecommunications Administrations (CEPT), Unwanted emissions in the spurious domain".

[i.13] ECC Recommendation (02)05: "European Radiocommunications Committee (ERC) within the European Conference of Postal and Telecommunications Administrations (CEPT), Unwanted emissions".

[i.14] EN/IEC 61508: "Functional safety of electrical/electronic/programmable electronic safety-related systems".

[i.15] EN/IEC 61784-3-series: "Industrial communication networks - Profiles - Part 3: Functional safety fieldbuses".

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

**alarms:** fixed or portable device that uses radio communication for indicating an alert condition at a distant location

**blacklisting:** ability of a device to avoid part of the available spectrum

**channel:** small frequency sub-band within the operating frequency band into which a Radio Signal fits

**dependability:** availability of relations between different behaviors

**duty cycle:** for the purposes of the Recommendation ERC/REC 70-03 [i.1] the duty cycle is defined as the ratio, expressed as a percentage, of the maximum transmitter "on" time on one carrier frequency, relative to a one hour period

NOTE 1: For frequency agile devices, the duty cycle limit applies to the total transmission.

NOTE 2: For specific applications with very low duty cycles and very short periods of transmissions, the definition of duty cycle should be subject to study.

**home and building automation:** business and residential control and system management by radio communication

**industrial:** relates to a place or an area where a manufacturing activity takes place

**listen before talk:** mechanism by which equipment first checks the availability of the channel before transmitting on that channel

NOTE: Also known as "listen before transmit".

**metering:** metering (water and energy) by radio communication

**Short Range Devices (SRDs):** radio devices which provide either unidirectional or bi-directional communication and which have low capability of causing interference to other radio equipment

NOTE: SRDs use either integral, dedicated or external antennas and all modes of modulation can be permitted subject to relevant standards. SRDs are normally "license exempt".

**specific SRDs:** SRDs that are used in specific applications (e.g. Applications of ERC/REC 70-03 [i.1], annexes 2 to 13)

**tag, transponder:** device that responds to an interrogation signal

**telegram:** data transmitted during one duty cycle

## 3.2 Symbols

For the purposes of the present document, the following symbols apply:

| | |
|---|---|
| E | Electrical field strength |
| f | frequency |
| fc | centre frequency |
| P | Power |
| d | distance |
| t | time |
| $\lambda$ | Wavelength |

## 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| | |
|---|---|
| DC | Direct Current |
| DCS | Distributed Control System |
| DFS | Dynamic Frequency Selection |
| e.i.r.p. | equivalent isotropic radiated power |
| EC | European Commission |
| ERM | Electromagnetic compatibility and Radio spectrum Matters |
| ERP | Enterprise Resource Planning |
| EU | European Union |
| FSS | Fixed Satellite Service |
| FWA | Fixed Wireless Access |
| IO | Input/Output |
| ISM | Industrial, Scientific and Medical |
| ITS | Intelligent Transport System |
| LBT | Listen Before Talk |
| LP-AMI | Low Power Active Medical Implant |
| MS | Mobile Station |

| | |
|---|---|
| NAMUR | Association for automation technology in the process industry |
| P&ID | Piping and instrumentation diagram |
| RFID | Radio Frequency Identification |
| RLAN | Radio Local Area Network |
| SRD | Short Range Device |
| TDMA | Time Division Multiple Access |
| WirelessHART | Wireless technology of the HART Communication Foundation |
| WLAN | WirelessLocal Area Network |
| WSAN | Wireless Sensor and Actuator Network of the PROFIBUS&PROFINET International |

# 4 Comments on the System Reference Document

**Esa Barck, Chairman of TFES comment:**

ETSI ERM/MSG TFES develops the Harmonised Standard EN 301 908 [i.2] for IMT technologies covering the range of frequency bands identified for IMT technology. The frequency band 2 300 MHz to 2 400 MHz is one band that has been identified for IMT technology and some countries in Europe have formally made known their plans to issue national spectrum authorisations across this band for mobile broadband technologies including IMT. In February 2011 ETSI started the Public Enquiry procedure on EN 301 908, Parts 19 and 20 [i.2] covering Mobile WiMAX IMT technology in the 2 300 MHz to 2 400 MHz band which is identified as Mobile WiMAX Band Class 1B.

In addition, 3GPP technical specifications also address this frequency range for unpaired UTRA and E-UTRA as Band identifier e) and 40 respectively.

## 4.1 Statements by ETSI members

**Zarlink Semiconductor comment:**

The band 2 483,5 MHz to 2 500 MHz is currently allocated to the Fixed, Mobile, and Mobile Satellite (Space to Earth) services on a Primary basis, and the Radiolocation service on a secondary basis, in ITU Region 1. However, Agenda Item 1.14 of WRC 12 proposes raising the status of the Radiodetermination Satellite (Space to Earth) service to primary service in all ITU Regions. There is no mention of how, if this band is to be allocated to industrial control type SRD, the radiation can be controlled such as to guarantee that there will not be harmful interference outside the industrial premises. For example, there is a BMW plant in the UK with many houses and main roads within 100 metres of the plant boundary. Unless very specific steps were taken to prevent radiation, which the plant owners would have little cognizance of, use of, for example, the Galileo RNSS system within some considerable distance of such an installation may not be possible.

The band 2 483,5 MHz to 2 500 MHz has also been designated by the CEPT for the deployment of Low Power Active Medical Implants (LP-AMI) because the band is relatively quiet in that there are few actual uses for avoidance of interference to the Mobile Satellite (Space to earth) service. Although there may in theory be interference from ISM applications, in practice the vast majority of these radiations have been found to be around 2 435 MHz and lower. The radiation from such devices is necessarily limited, both on safety grounds, and by Radio Regulation 15.13, and additionally, does not have a 100 % duty cycle - in the case of microwave ovens, only 50 % when operating, while the activity factor (actual use) is much lower.

Although the LP AMI application cannot claim any protection for its communications, the use of the band for 100 mW, high duty cycle devices will effectively prevent the employment of anyone using such a LP-AMI within an industrial complex where such systems are employed. This is because 100 % (or even high) Duty Cycle operation will mean that such devices will be operating with receivers in 'partial wake up' mode for extended periods, thus leading to early battery depletion. Thus the installation of such a system in an industrial complex would lead to such employees having to have their employment terminated at substantial cost, and companies installing such systems would need to be warned of this before hand, as well as those neighbouring companies whose employees could also be affected. There would also be a negative impact on visitors to such sites. Unless very specific steps are taken to minimize radiation outside the industrial premises, patients with Active Medical Implants in adjacent residential or even hospital areas could also be adversely affected, and this would result in a degree of legal uncertainty for the owners of such sites.

The result of the effects both on LP-AMI and on the Radiodetermination Service means that the commercial justification for a system in this band is very much weakened. It would prove extremely difficult to ensure that re-organisation within a plant did not negate any steps taken to constrain the radiation to within the plant boundaries.

**Medtronic comment:**

Medtronic object to the inclusion of the frequency band 2 483,5 MHz to 2 500 MHz. This band is already included in annex 12 of ERC/REC 70-03 [i.1] for Ultra Low Power Active Medical Implants (ULP-AMI).

**Deutscher Amateur-Radio-Club (DARC e.V.) comment:**

DARC note that no details of the spectrum access are mechanisms are described. In the case of those applications using 100 % (or near 100 %) duty cycles, the spectrum access mechanism is of necessity pre-emptive, and unless LBT techniques are used, predatory. This will be especially so in the case of frequency hopping systems, and will therefore have a distinct probability of causing interference to other systems. Although these systems are envisaged as being located totally within the factory, it is most unlikely that the radiated signal will be confined solely to the factory premises - several examples may be found of factories with housing very close to their boundaries. This could lead to the situation where an amateur station with an e.i.r.p. of +80 dBm was geographically close to such a system, suggesting that an alternative frequency range is desirable.

DARC also notes the suggestion of the band 2 483,5 MHz and 2 500 MHz being suitable: because of the difficulty of ensuring that the radiation is confined to factory itself, it is probable that interference to the radio determination satellite service will occur. Agenda Item 1.18 of the World Radio Conference is proposing the radio determination satellite service be raised to Primary status on a global basis, which provides a definite chance of incompatibility.

# 5 Market information

## 5.1 Market evolution and potential

Wireless Automation is used since a few years in a larger scope, but still at the beginning of its growth phase.

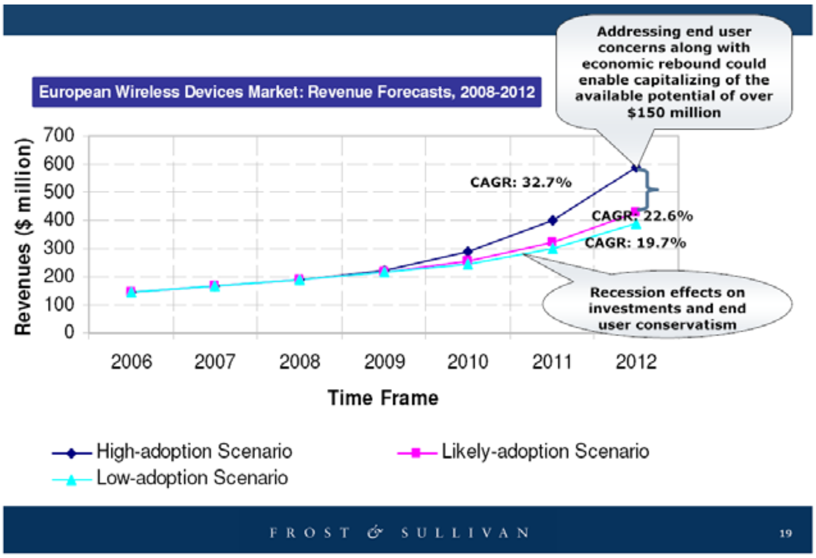



**Figure 1: Forst & Sullivan study**

Figure 1 is a copy out of the VDI Wireless Conference 2009, "Wireless Solutions in Process and Discrete", March 11th 2009.

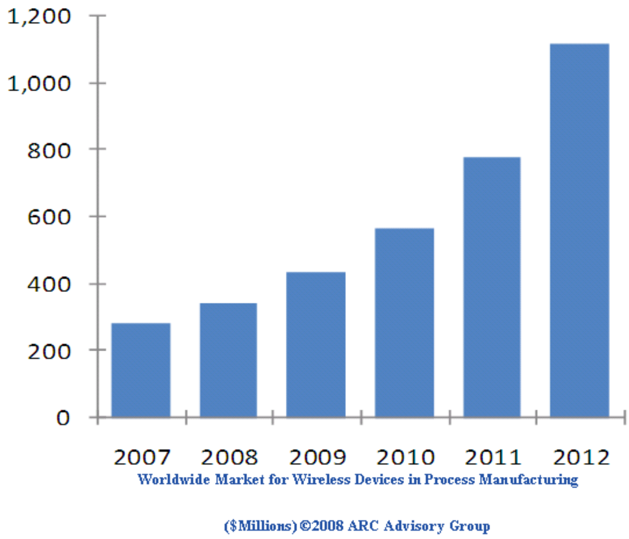



**Figure 2: ARC study**

Figure 2 is a copy of a presentation from ARC to the ETSI Board #67, 13 June 2008: "Wireless in Process Automation Trends and Outlook".

Figures 1 and 2 show the different market estimates, the top one showing the importance of suited technologies in order to grow and fulfil the end user expectations to improve productivity.

First dedicated technologies have just been developed (WirelessHART technology for process automation, WSAN activity of PROFIBUS & PROFINET International for the factory automation; see IEC working group IEC SC65C/WG16 (EN/IEC 62591 [i.4]) and IEC SC65C/MT9 (IEC 61784-2 [i.3]) enabling an even larger growth and market.

Compared to RFID or more simple SRDs the volume of devices may be lower but their value and effect for production is much larger as well as the turnovers. A single wireless automation device costs in the range between 200 € to 1 500 € compared to simple RFID tags which should be significantly below 1 €.

EXAMPLES:

- **Process Automation:** Currently close to 30 Million field bus devices (mainly single sensors and actuators) are installed already in process automation. Predominantly (ca. 90 %) the digital information is not used in the distributed control system (DCS) as only the analogue part is used to control the processes. In today's environment of a high pressure to improve productivity but especially also due to energy efficiency and environmental requirements there is a high need to access also the digital part. This is only possible with additional digital expensive infrastructure (new wires) and bus gateways in the extended process plants. In total only roughly 15 % of IO devices in process automation are Fieldbus devices, and wireless enables new use cases at positions not economical so far. So in total there is a large growth potential.
Therefore, it is estimated that within short time (10 years).

- Most of this unused information will be tapped by wireless adapters (25 Mio. pieces).

- A similar amount of new sensors/actuators will be installed predominantly with wireless connection (20 Mio. pieces.) in order to get much more detailed information from the processes, to better control them and increase efficiency and lower waste products.

- **Factory automation:** Currently more than 30 Million field bus devices are installed already in factory automation applications, mainly more complex devices like remote IO boxes with e.g. 8-50 IO each. It can be estimated that roughly 5 Mio new bus nodes are sold per year. Here always the digital information is directly used in the control systems. Still all sensors and most actuators (except electrical drives) are typically wired with single wires and connectors. It is these wires and connectors which are most likely to fail or be a problem in many installations as many of them are moving or endangeredto be hit by material or service persons. In average 10 times the amount of field bus devices are connected sensors and actuators:
    - If only some of them would be directly wireless in future (the ones with movements or flexibility needs e.g. ~10 %).
    - This gives a minimum estimate of 5 millions wireless devices per year in factory automation.

Payback time of such wireless automation equipment is typically in the range of a few month, which is very short compared to the life time of the machines and devices. The typical lifetime of such industrial applications is very often much higher than 10 years.

Therefore, and because the wireless devices help to keep in total European industry competitive, the economic impact of wireless automation devices in Europe is significantly higher than just the devices value creation itself.

Down the value creation chain, the economic benefit increases significantly, where wireless devices are the enablers:

- Device Manufacturers (innovative and more devices to sell).
- Subsuppliers to machine builders (improved subunits with easy integration).
- Machine builders (improved functionality).
- Plant engineering (easier, faster planning and commissioning).
- Producers (higher productivity, higher availability/less downtime, higher quality).

### 5.1.1 The socio-economic benefits

Wireless communication in industrial applications has the following benefit for the industrial manufacturing process:

- Increased productivity:
    a) Reduced down-time of processes and machinery (due to broken cables/connectors).
    b) Improved product quality as wireless allows to reach a higher level of automation.
    c) Faster building and commissioning of industrial sites (higher flexibility when using wireless).
    d) Lower installation cost compared to wires/connectors (especially in large, difficult to reach, or harsh environments).
    e) More efficient manufacturing process due to increased information flow.
    f) Higher flexibility due to easier reconfigurability of manufacturing systems.
- Lower energy consumption due to energy efficient wireless communications versus current loop (4 mA to 20 mA) devices.
- Wireless will enable new possibilities for manufacturing automation which could not be done via wired techniques.
- Wireless can also improve the safety in a work environment, where cabling is difficult e.g. in rotating or moving machines, or in aggressive environment.

### 5.1.2 Views from the international user association of automation technology in process industries

NAMUR is an example of an international user association of automation technology in process industries. NAMUR provides "NAMUR Recommendations" for wireless standards, the technology employed and solutions from different manufacturers, which ensure that these provide the necessary functions and security of investment for sustainable use in the process industry, see NE 124 [i.9] and NE 133 [i.10].

## 5.2 Information for sharing and compatibility studies

The majority of the communicating devices do not have line of sight, especially those that are movable or mobile. Furthermore, the environment can also be characterised by moving obstacles.

Receiver requirements which will be considered to ensure a reliable communication within a manufacturing environment include receiver sensitivity, interference blocking, adjacent channel selectivity, spurious response rejection, co-channel rejection, third order intermodulation (IM3) suppression.

Most industrial applications cannot use frequencies above 6 GHz due to the quasi optical propagation behaviour and requirement for line-of-sight wireless communications.

Additional market information on industrial wireless applications is given in annex A.

For spectrum and sharing studies the following assumptions can be made:

In a larger industrial plant, if a chemical or oil-/and gas industry process plant ("process automation") or e.g. an automotive discrete manufacturing plant (discrete or "factory automation"), there are and will be always many different wireless systems and technologies for different functions operating simultaneously in the same area.

With reference to table 1, the subdivision of such systems into three classes can be typically done:

- Cell or subunit automation.
- Factory hall or plant subunit automation.
- Plant level wide applications.

Within these three classes, always several of these wireless systems can be in close proximity, so that they overlap ("interference" range) partially or completely and therefore enough bandwidth space is needed to resolve media access conflicts not only in one but especially also between several independent similar or different systems.

NOTE 1: Bandwidth space is needed for media access and conflicts resolution either by:

a) LBT on one channel; or

b) Re-transmissions and frequency hopping in case of a collision based system. In both cases a typical practical limit is at 30 % to 40 % media or channel utilization, where the spectrum efficiency drops to nearly zero, therefore a lower value of 20 % has been assumed in the bandwidth requirement estimation for each of the classes, in order to have enough margin for reliability and other unplanned systems (e.g. bypassing/temporary other wireless systems using the same frequency band/channels).

Therefore there is a need to have a lower frequency utilisation (see note 2) as a kind of duty cycle for the systems to ensure reliable communication. Nevertheless, the Master of such a system (1 out of the assumed e.g. 30 wireless devices) is in need of having a higher transmission duty cycle of up to 100 % on one channel, to handle the 30 very low duty cycle devices in a deterministic manner (TDMA schemes used).

NOTE 2: Frequency utilization is defined here as the resource usage within a certain frequency band which can be seen as a duty cycle: Bandwidth used for a certain time related to available maximum bandwidth and observation period.

The classes are described below in more detail.

- **Cell** (or subunit) automation:

  Lowest control system level, can be a part of a line in an automotive plant or a normal discrete manufacturing cell or a subunit in process automation (e.g. a reactor with a local control to which sensors and actuators are connected). Typically lower range (e.g. 10 m to 30 m range) but most demanding for latency and robustness, are capable to live with fast movements, integrated antennas and many obstacles (nearly complete shielding).

  - One such cell unit has one wireless system with in average 30 devices.
  - Up to 10 such units/manufacturing cells can be in close proximity, so that their interference area overlaps.
  - The area related local device density at 10 m range therefore is typically 10x30 devices per 10x10 $m^2$ or 0,33 to 3 devices per $m^2$ (at 30 m to 10 m range respectively).
  - The cell automation data packets as such are typically quite small and have 16 octets on air (e.g. 4 octets of user data, 12 octets for addressing, control and error protection) and have to be sent every 50 ms in each direction.

- **Factory hall** (or plant subunit) automation:

  Medium Control System level, where e.g.:

  a) whole production lines or moving applications (e.g. moving through a factory hall in discrete manufacturing e.g. automated guided vehicles, rail hanging power screwdrivers), or

  b) whole production units in process automation:

     - Cover a larger area (e.g. 100 m x 100 m). This is solved by an industrial WLAN or a mesh type technology (TDMA schemes used) to safely cover a larger area with.
     - In average 100 devices and still low latencies.

  Also here the master is in need of a higher duty cycles and high power to cover the range without line of sight:

  - Up to 5 such independent systems can be within range of each other (are within "interference" range).
  - The area related local device density at 100 m range therefore is approx. 5 x 100 devices per 100 x 100 $m^2$ or 0,022 per $m^2$ at 100 m range.
  - The hall/subunit automation data packets as such are typically medium size with 200 octets on air (e.g. 140 octets of user data, 60 octets for addressing, networking, control and error protection) and have to be sent every 200 ms in each direction.

- **Plant level wide** applications:

  Control system level covering up to the whole plant, typically an industrial mesh technology:

  - Able to cover e.g. 1 km x 1 km but typically with mesh technology to increase robustness against typical industrial influences (moving obstacles, interference/coexistence).
  - One such mesh system can have up to 1 000 connected devices, but each device only having to cover a smaller range (100 m) and the mesh covers the larger distances needed, without excessive power needs.
  - There may be up to 3 independent such mesh networks operating in parallel in the whole plant.
  - Up to max. 50 devices of the 3 clusters can be within range of each other (are within "interference" range).
  - The area related local device density at 100 m range therefore is approx. 50 devices per 100x100 $m^2$ or 0,025 per $m^2$ at 100 m range.

- The plant level automation data packets are typically medium size with 105 octets on air (e.g. 50 octets of user data, 55 octets for addressing, networking, control and error protection) and have to be sent every 500 ms in each direction.

For Up and downlink information, two of the above defined telegrams have to be sent per update interval.

All of these 3 levels are operated in parallel (partially or completely overlapping interference area), and often by different operators and connected to different Control Systems. Each of the many wireless systems has to be allowed to switch on and off and vary the number of connected active devices and data amount transferred, depending of the needs of the many different production cells/subunits/ lines in order to maximise individually production, quality, safety and do service, troubleshooting and installation work on the productions units.

Parallel means that at most parts of the plant, the three "wireless" classes operate overlapping, preferably in the same frequency band for maximal flexibility of coexistence management reasons, to increase spectrum efficiency and to have the same needed spectrum properties like industrial-interference-free, power efficiency (range) and bending/damping by obstacles.

Normally, in total more than 70 MHz of spectrum would be required to support applications from the 3 classes to operate seamless within a given environment without any restriction. This would still require a clever site planning which is not always possible as the different wireless solutions are from different vendors. However, recent and future developments of more intelligent sharing mechanisms will facilitate automatic seamless operation of these 3 classes even in less spectrum is made available.

The total estimation of needed spectrum to share can be estimated from table 1 by adding up the spectrum estimated for the three classes to be in the order of 76 MHz of continuous spectrum.

# 6 Technical information

## 6.1 Presentation of the system or technology

Typical industrial sites are manufacturers of goods or providers at any place within the delivery chain towards these goods (e.g. oil/gas/energy producers, suppliers of parts or components of these goods up to final assembly of the goods, after- production processes such as water/waste management).

Examples of existing communication network solutions are standardized in EN/IEC 61784-2 [i.3] and EN/IEC 62591 [i.4] for wireless solutions for so-called PROFINET based on IEEE 802.11/IEEE 802.15.1 [i.6], [i.7] and WirelessHART (see EN/IEC 62591 [i.4]) based on IEEE 802.15.4 [i.8].

Industrial automation requires "robust" wireless technologies to be used for their wireless links in industrial applications. More and more wireless solutions are being considered nowadays for these applications.

The advantages of wireless are beneath savings of often complex and expensive cabling, cable protection and plugs the increased mobility and flexibility as well as the wear and tear free transmission medium. These advantages are particularly high in the area of:

- Monitoring and mobile worker communication.
- Wireless sensors and actuators at moving parts.

Different functions can be mastered substantially more efficient by a wireless network of data acquisition terminals, robotic type equipment or automated guided vehicles.

For the sensor and actuator type of applications in industrial automation, the main requirement is the real time behaviour. Determinism for process industry. Real time means a maximum response time defined by the type of application. E.g. on the factory floor of discrete manufacturing, very short latencies of a few ms and a very high reliability (high robustness) is necessary in order to avoid interruptions in the manufacturing process.

In higher levels of the automation hierarchy e.g. at the control or enterprise level, the data volume rises, so throughput, security and reliability becomes more important, but real–time communication requirements decrease.

To meet these requirements, both application categories require specific wireless technologies for specialised sensor/actuator networks. Some technologies being developed for these applications are listed above.

Industrial automation equipment is typically designed in a way that it is not interfered by other wireless applications present in the industrial environment. If a critical wireless link would be interrupted (interfered), or not respond instantaneously, safety measures will take effect immediately.

To achieve the required performances for different industrial wireless applications, it is important to achieve either short latencies or high throughput, in addition to range and reliability, etc. Therefore, industrial users very much depend on the chosen technical solutions for their seamless operational procedures, i.e. a high dependability is envisaged.

In addition, the manufacturing processes require often to use more than one wireless technology simultaneously within the same area or environment. One option is to use a coexistence management system in industrial automation applications according to IEC 62657-2 [i.11] or using any other appropriate sharing mechanisms meeting the specific demands of the industrial applications.

## 6.2 Detailed technical description

Table 1 shows the extreme low latency and application availability requirements of many industrial wireless applications.

In a larger industrial plant, if a chemical or oil-/and gas industry process plant ("process automation") or e.g. an automotive discrete manufacturing plant (discrete or "factory automation"), there are and will be always many different wireless systems and technologies for different purposes in parallel to each other (partly or completely overlapping).

The subdivision of such systems into three main classes can be typically done according to table 1 into:

- cell or sub-unit automation;
- factory hall or plant sub-unit automation; and
- plant level automation.

Details behind figures 3, 4, 5 and 6 are described in clauses 6.1 and 6.2.

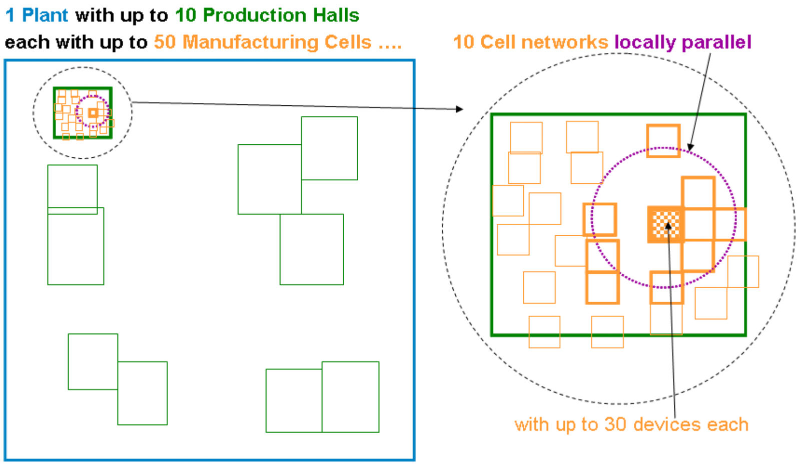



**Figure 3: Example of a 1 plant with 10 production halls and 50 manufacturing cells**

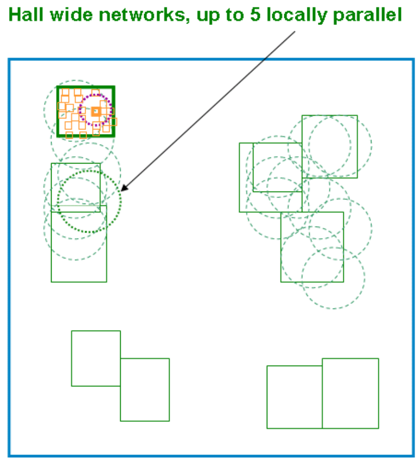



**Figure 4: Example of hall wide networks, up to locally parallel**

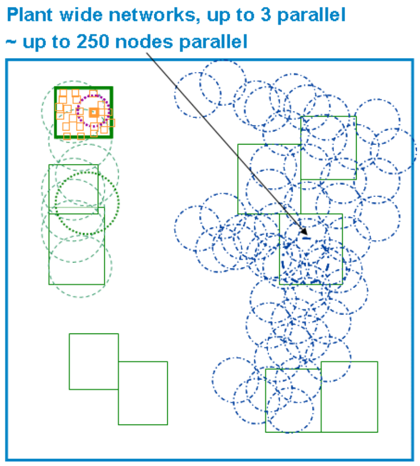



**Figure 5: Example of plant wide networks, up to 3 parallel**

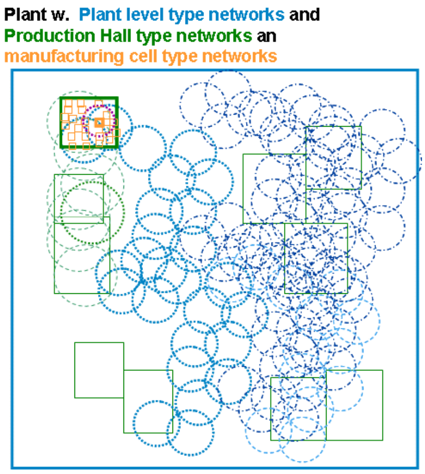



**Figure 6: Example of a combination of 3 classes**

**Table 1: Unit density and performance requirements**

| | Manufacturing cell | Factory hall | Plant level |
|---|---|---|---|
| **Indoor/outdoor application** | indoor | mostly indoor | mostly outdoor |
| **Spatial dimension LxWxH [m$^3$]** | 10 x 10 x 3 | 100 x 100 x 10 | 1 000 x 1 000 x 50 |
| **Number of devices (typically)** | 30 | 100 | 1 000 |
| **Number of parallel networks (= clusters)** | 10 | 5 | 5 |
| **Number of such clusters per plant** | 50 | 10 | 1 |
| **Min. Number of locally parallel devices** | 300 | 500 | 250 |
| **Network Type** | Star | Star/Mesh | Mesh |
| **S, Typ. packet size [on air, byte]** | 16 | 200 | 105 |
| **Maximum allowable latency (end-to-end) incl. jitter/retransmits [ms]** | 5 ± 10 % | 20 ± 10 % | 20 ± 10 % |
| **DC, Max. on-air duty cycle related to media utilisation (see clause 5)** | 20 % | 20 % | 20 % |
| **T, Update Time [ms]** | 50 ± 10 % | 200 ± 10 % | 500 ± 10 % |
| **Packet Loss Rate (outside latency)** | $10^{-9}$ | $10^{-9}$ | $10^{-9}$ |
| **E, Spectral efficiency (typically) [Bit/s/Hz]** | 1 | 1,18 | 0,13 |
| **B, Resulting min. Bandwidth requirement [MHz] (via spectral efficiency, formula see appendix) (see note)** | 8 | 34 | 34 |
| **Application availability** | exceeds 99,999 % (less than 300 s accumulated outage per annum). | | |
| **Typical operational distance** | depends on individual use case and frequency of operation. | | |
| NOTE: To account for up and downlink information, 2 telegrams have been assumed. | | | |

$$B = \frac{2 \cdot N \cdot S \cdot 8 \cdot}{T} \cdot 1000 \cdot \frac{1}{DC} \cdot \frac{1}{E}$$ ; variables as defined in table 1

Where:

B = Bandwidth

E = Spectral efficiency

T = Update Time

DC = Max. on-air duty cycle related to media utilisation

S = Packet size

The three listed categories will nearly always be existing in parallel in a production site, therefore the bandwidth spectrum needs have to be added up, which results in 76 MHz Bandwidth, which does not necessarily has to be contiguous spectrum.

A relatively high robustness or determinism of latencies as well as a high reliability of delivering field device information or control signals are required for wireless automation. High robustness in time-variant environments (moving objects) with other wireless systems being present means that the required signals necessarily demand a frequency hopping approach and blacklisting, resulting in wide band systems to provide the required performance. The demand for high reliability means that also the "difficult" cases in the application scenarios (for example where the radio propagation environment is challenging due to several machine parts, humans or production material parts may block the radio link and the link is only maintained via several reflections) are covered. This can be translated into a total higher transmit power margin.

# 6.3 Technical parameters and implications on spectrum

## 6.3.1 Status of technical parameters

### 6.3.1.1 Current ITU and European Common Allocations

Table 2 shows the excerpt from the European Common Allocation table for the candidate bands.

**Table 2: Existing allocations in the candidate bands**

| Frequency band [MHz] | Allocations | Applications |
|---|---|---|
| 2 360 to 2 400 | Amateur<br>FIXED<br>MOBILE<br>Radiolocation | Aeronautical telemetry<br>Land mobile<br>SAP/SAB and ENG/OB<br>Amateur |
| 2 483,5 to 2 500 | FIXED<br>MOBILE<br>MOBILE-SATELLITE<br>(SPACE-TO-EARTH) | IMT-2000/UMTS<br>ISM<br>Land mobile<br>MSS Earth stations<br>SAP/SAB and ENG/OB |
| 5 150 to 5 250 | MOBILE EXCEPT AERONAUTICAL<br>MOBILE<br>FIXED-SATELLITE<br>(EARTH-TO-SPACE | Aeronautical Telemetry transmission<br>Emergency Services<br>Radio LANs<br>MSS feeder links<br>Radiodetermination applications (within the band 4500-7000 MHz for TLPR application) |
| 5 725 to 5 850 | Amateur<br>Mobile<br>RADIOLOCATION<br>FIXED-SATELLITE<br>(EARTH-TO-SPACE | Amateur<br>Non-specific SRDs<br>Radiodetermination applications<br>Tactical radar<br>RTTT<br>BFWA<br>ISM |
| 5 850 to 5 925 | FIXED<br>FIXED-SATELLITE<br>(EARTH-TO-SPACE)<br>MOBILE | Detection of movement and alert<br>BFWA<br>ISM<br>Non-specific SRDs<br>FSS Earth stations<br>ITS (Intelligent Transport Systems) |

### 6.3.1.2 Sharing and compatibility studies (if any) already available

There are no studies available for industrial applications using any of the frequency bands provided in table 3.

### 6.3.1.3 Sharing and compatibility issues still to be considered

There is a need to study the compatibility of these wireless industrial applications with other services that operate in the intended bands provide by table 3. More details with respect to the specifics to be taken into account in such study are provided in clause 5.2.

## 6.3.2 Transmitter parameters

### 6.3.2.1 Transmitter Output Power/Radiated Power

EIRP up to 250 mW is required.

### 6.3.2.2 Antenna Characteristics

No restrictions on antenna characteristics.

### 6.3.2.3 Operating Frequency

To accommodate the different needs for the various applications covered by the present document, several bands need to be identified. Although due to propagation characteristics and the predominant presence of electromagnetic disturbances in an industrial environment, the actual range of interest is limited to the 1,5 GHz frequencies up to 6 GHz.

Table 3 contains a list of bands identified as potential candidates.

The preference is to have this new spectrum close to or adjacent to bands which are globally already available and for which industrial wireless technology has already be developed.

To accommodate the different wireless industrial applications using today's technology, about 76 MHz of spectrum is required. If a non-contiguous spectrum is considered then the minimum width of at least one subband should be in the range of 40 MHz. The others should at least around 20 MHz due to fading/multi-path effects.

### 6.3.2.4 Bandwidth

As different technologies are used, the typical occupied bandwidth for a single device varies between 1 MHz and 20 MHz. Specific applications like location tracking may even use the complete available (sub-)band.

Frequency Hopping as well as non-frequency hopping technologies are used.

### 6.3.2.5 Unwanted emissions

The unwanted emissions will be in accordance to ECC Recommendation (02)05 [i.13].

## 6.3.3 Receiver parameters

### 6.3.3.1 Spurious emissions

The spurious emissions will be in accordance to ERC/REC 74-01 [i.12].

### 6.3.3.2 Receiver sensitivity

Most of the technologies used in the industrial applications are based on specifications such as IEEE 802.11 [i.6], IEEE 802.15.1 [i.7] and IEEE 802.15.4 [i.8]. Therefore, the relevant receiver parameters including the receiver sensitivity can be found in those standards.

### 6.3.3.3 Other receiver parameters

The performance of certain sharing mechanisms may require certain specific receiver requirements. The sharing study will show if additional receiver parameters are required.

## 6.3.4 Channel access parameters

For maximised spectrum efficiency, including sharing among all wireless industrial applications present, a spectrum sharing mechanism appropriate for industrial applications is required.

An example of that is Frequency Agility. Frequency Agility is the ability of a system to operate according to frequency or channel assignments of a centralized or distributed control mechanism, which will define the configuration of all devices within an industrial site or subarea thereof, Configurations may change over time depending on the application requirements. If non-contiguous spectrum is assigned, then the Frequency Agility feature is supposed to operate across all assigned sub-bands.

## 6.4 Information on relevant standard(s)

As currently no specific allocation exists for wireless industrial applications, a harmonised standard should be developed.

# 7 Radio spectrum request and justification

## 7.1 General

Several frequency bands are necessary that provide for different coverage areas to address all the different operational requirements for wireless industrial applications, sometimes operating simultaneously in parallel and covering very different operational environments.

While the non-critical wireless links could use existing spectrum and comply with existing rules and ETSI standards, new frequencies (outside the 2,4 GHz and other SRD bands) need to be identified for the more demanding/critical wireless links in industrial applications. The preference is to have this new spectrum close to or adjacent to bands which are globally already available and for which industrial wireless technology has already been developed.

To address the specific needs for wireless industrial applications, the following requirements are identified:

- The use of specific technologies in order to be robust in a dynamic and multi-path environment.
- Frequency bands (and corresponding requirements according to clauses 6, 7 and 8), which are globally available or adjacent to globally available bands as to use existing technology developed for these bands.
- Frequency bands above 1,5 GHz to avoid interferencefrom welding machines and below 6 GHz due to the quasi optical propagation behaviour above and requirement for non-line-of-sight wireless communications.

## 7.2 The current situation

Existing solutions for industrial wireless communication exist for frequencies such as 900 MHz (US only), 1 880 MHz to 1 900 MHz (DECT), the 2,4 GHz ISM-band or the 5 GHz WLAN bands.

Currently, the industrial automation applications make use of existing spectrum allocated for generic SRDs. The 2,4 GHz band is a commonly used band and this is regulated by annex 1 (10 mW with no restriction) and annex 3 (100 mW with restrictions) of ERC/REC 70.03 [i.1]. However, power levels in excess of 10 mW (annex 3) require an automatic sharing mechanism, which is incompatible with the needs of industrial wireless links.

Up to now, the intended robust wireless communication was assured by using a coexistence management system in the industrial premises according to IEC 62657-2 [i.11].

Security mechanisms are always part of the communication architecture of industrial wireless applications to defend the industrial user against attacks. Pervasive action plans (so-called "safe-modes") do also exist to encounter intended and unintended interference created by others (e.g. jamming). This may include moving to different frequencies. Security standards for industrial applications are available such as the IEC 62443 series [i.5].

For wireless industrial applications in non exclusive harmonised frequency bands some ethical issues may arise. For this, it is to observe the inherent less than 100 % reliability of wireless communication and the non-exclusive use of the frequency space. For complete installations supplied with wireless technology, sufficiently effective safety measures can be implemented in the equipment to prevent accidents as the result of failure of the wireless link. For subsystems, like actuators and valves, this is not possible by design. The end-user of the subsystem needs to assess the risks the particular subsystem may cause if the wireless link fails, as exclusive access to the spectrum (in non-exclusive bands) cannot be ensured.

Contrary to usual frequency band utilisation, where several uncoordinated users and their radio equipment does not interfere with each other, in an industrial wireless environment, the coexistence management according to IEC 62657-2 [i.11] and the detailed access mechanisms of the utilized technologies, e.g. WirelessHART according to EN/IEC 62591 [i.4], WSAN, etc. ensure proper operation.

As an example, an industrial protocol compliant with EN/IEC 62591 [i.4] allows in a meshed network to operate several thousand devices over several years without any collision among themselves. The basis for this is a clock synchronized slot assignment and a network manager tool in an access point (gateway) that assigns the allowed slots to transmit data.

However, operation in a commonly used SRD band might prevent a wireless industrial application to operated as intended hence why another solution need to be sought.

## 7.3 The new proposal

### 7.3.1 Critical wireless links in industrial applications

Some of the applications shown in annex A require a strictly deterministic behaviour of the wireless communication links. The availability, reliability, predictability, dependability, immunity and quality of industrial wireless equipment are quite different from many other short range applications. Therefore spectrum typically used for mass market generic type of SRD applications might not be adequate for these industrial applications. The candidate frequency bands provided in table 3 are not supposed to become generic SRD bands but should be limited to certain specific applications.

The present document highlights the need for new spectrum to be designated that corresponds to the following needs:

1) The critical wireless links in industrial applications assume a certain priority in European spectrum designation.

2) The requested band should be specific for these industrial applications and not be overlapping with the existing SRD bands.

3) This new band is for harmonised use across Europe.

Once the ECC has reviewed this request and new spectrum has been designated by means of an appropriate ECC deliverable, ETSI will develop a harmonised standard for these critical wireless links in industrial applications. It is assumed that, apart from the typical Radio spectrum parameters, this standard will also address the following issues:

- Specific receiver parameters as specified in clause 6.3.3.

- Channel access parameters as specified in clause 6.3.4.

Table 3 provides an overview of candidate bands to be considered by the CEPT when studying the requirements and compatibility issues for the industrial applications described in the present document.

### 7.3.2 Non-critical wireless links in industrial applications

Other, non-critical wireless links can make use of the existing bands allocated to- as well as the standards developed for SRDs. It is understood that operation in some of the SRD bands is subject to using specific mitigation techniques as mandated by the applicable regulation/standard and they would apply to any SRD also those used for industrial applications as it is obvious that a variety of SRD applications might already be present in the industrial environment.

It is understood that wireless industrial applications operating in non-exclusive bands, need to co-exist with any other industrial or non-industrial application in the same band and therefore will not enjoy a higher priority like the critical wireless links described in clauses 5 and 6.

### 7.3.3 Proposed candidate frequency bands

Requirement to use radio systems in an area where electromagnetic emissions occur results in a request of spectrum above 1,5 GHz. Requirements of non-line-of-sight communications and power efficiency results in request of spectrum below 6 GHz.

Table 3 describes the proposed candidate frequency bands to be considered.

**Table 3: Proposed candidate frequency bands to be considered**

| Candidate band [MHz] | Remarks |
|---|---|
| 2 360 to 2 400 | This is currently used for Amateur, mobile, fixed and radiolocation. |
| 2 483,5 to 2 500 | This is currently used for mobile, fixed, and mobile-satellite. |
| 5 150 to 5 250 | This may require sharing mechanism with RLANs. |
| 5 725 to 5 850 | Additional regulatory parameters may be needed for compatibility with other services. This could include for example sensing (DFS) or light licensing. |
| 5 850 to 5 875 | This is the upper part of the FWA, SRDs, ISM2, ITS, military systems, fixed satellite applications. |
| 5 875 to 5 925 | This band is in use for FS in some European countries and for FSS uplinks. The band is also allocated to ITS. |

# 8 Regulations

## 8.1 Current Regulations

There exists no specific regulation for industrial applications at this moment. Wireless industrial applications that currently exist on the market make use of existing spectrum designated for generic or some specific short range devices and therefore fall within the scope of any of the existing annexes of ECC Recommendation 70.03 [i.1]. However, the requirements of critical wireless links in industrial applications cannot be fulfilled when operation in these SRD bands, hence why exclusive (specific SRD) spectrum is required as soon as possible.

## 8.2 Proposed Regulation and justification

Table 4 provides an overview of the candidate bands for these new wireless industrial applications. The preferred type of deliverable to accommodate these applications would be a new entry into the ERC/REC 70.03 [i.1]. At a later stage, an even more harmonised approached is envisaged by a new entry into the EC decision for Short Range Devices.

**Table 4: Proposed regulations**

| Frequency band [MHz] | Maximum mean power and mean power density (e.i.r.p.) [mW] | Duty cycle [%] | Channel spacing | Remarks |
|---|---|---|---|---|
| 2 360 to 2 400 | 100 | 100 | No requirements | See note |
| 2 483,5 to 2 500 | 100 | 100 | No requirements | See note |
| 5 150 to 5 250 | 200 | 100 | No requirements | See note |
| 5 725 to 5 850 | 250 | 100 | No requirements | See note |
| 5 850 to 5 875 | 250 | 100 | No requirements | See note |
| 5 875 to 5 925 | 250 | 100 | No requirements | See note |
| NOTE: See clause 6.3.4 for Channel access parameters. | | | | |

## 8.3 Requested ECC and EC actions

ECC is requested to undertake studies on the proposals for new spectrum for these industrial applications. It is requested that these studies are performed within a time frame of 12 months.

It is also expected that the ECC and EC actions will result in an appropriate regulation resulting in harmonized European conditions for the availability and use of the radio spectrum for these industrial applications.

# Annex A: Detailed market information - Market size, Applications and requirements

## A.1 Range of applications

### A.1.1 Overview

The so called "Process Industry" uses predominantly continuous production processes to produce or process large quantities or batches of a certain product (like fluids, chemical, or an "endless" product like e.g. wires, cables).

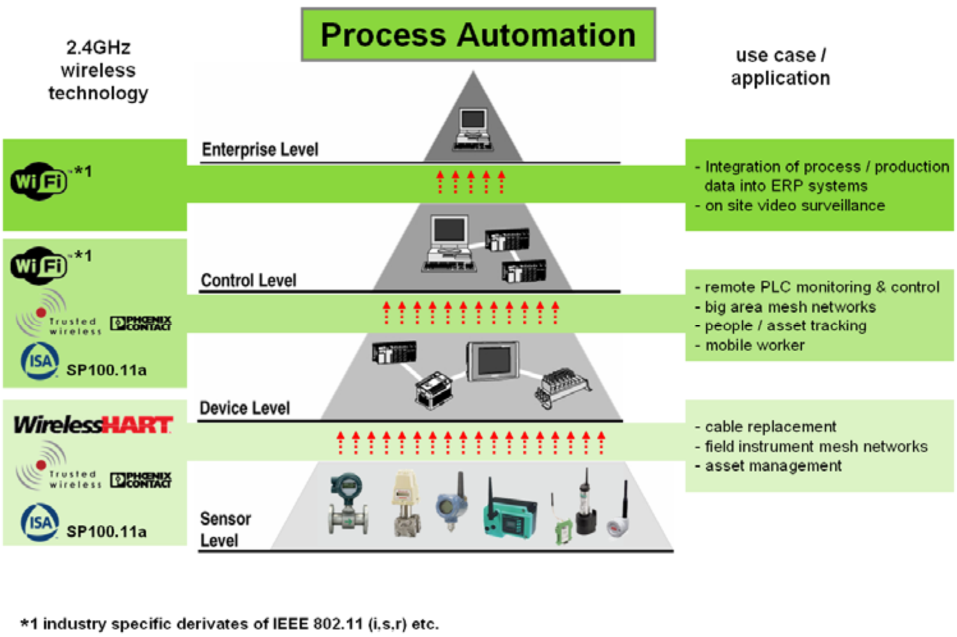



**Figure A.1: Automation hierarchy in a process plant with example technologies used**

On the sensor level you can find mesh networks for field instruments, based on different wireless mesh protocols (wireless HART specified in EN/IEC 62591 [i.4]), or not yet standardized protocols like Trusted Wireless). The mesh structure helps to achieve a large range coverage with standard low power levels and be robust.

The process applications do also require deterministic behaviour (no adaptively to e.g. bypassing other wireless users) but do require latencies more in the range of e.g. a second. Compared to factory automation it covers much bigger areas, which can be done very efficiently by a mesh network, the end nodes (sensors) partly have to be able to live from a battery for several years.

Factory Automation is used as synonym for discrete manufacturing where products are assembled, tested, packed etc. in many discrete steps (automotive and general consumer good production). Typically every single step is controlled by many sensors and actuators, all of them classically wired. Many of these wires (and their connectors) are often stressed by repeated movement and other harsh conditions.

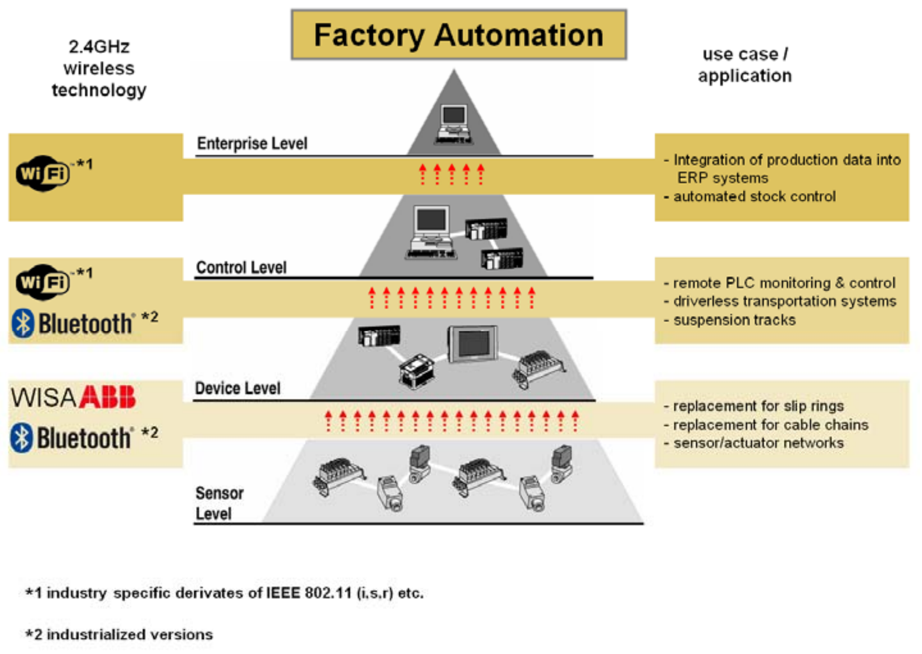



**Figure A.2: Automation hierarchy in a discrete manufacturing factory plant with example technologies used**

In factory automation determinism and low latency is important as the typical use case might involve many wireless sensors and actuators in order to improve the productivity (higher availability) compared to wired sensors/actuators at difficult locations. The signals are typically used in the online control.

Both, the factory and process automations use low latency, reliable and secure communications.

## A.1.2 Category A: Low latency applications

The following applications are examples for industrial wireless application with requirements for extreme low latency. One of the most important reasons for wireless usage in the industry is the control of moving parts. The traditional solutions are slip rings, or cable chains. Both are very expensive, need a lot of maintenance and are prone to errors.

Some examples are illustrated in figures A.3 to A.8.

### A.1.2.1 Robotic arms

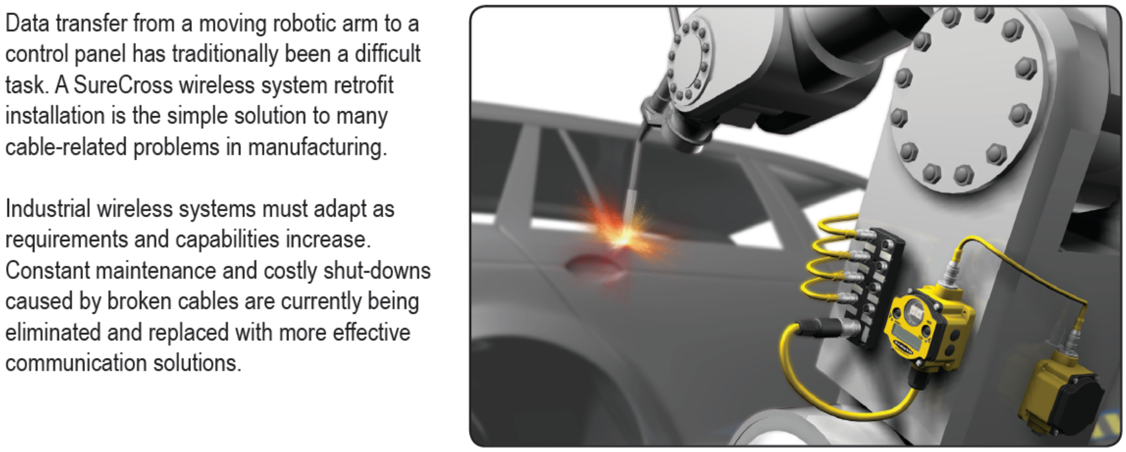



**Figure A.3: Robotic arms**

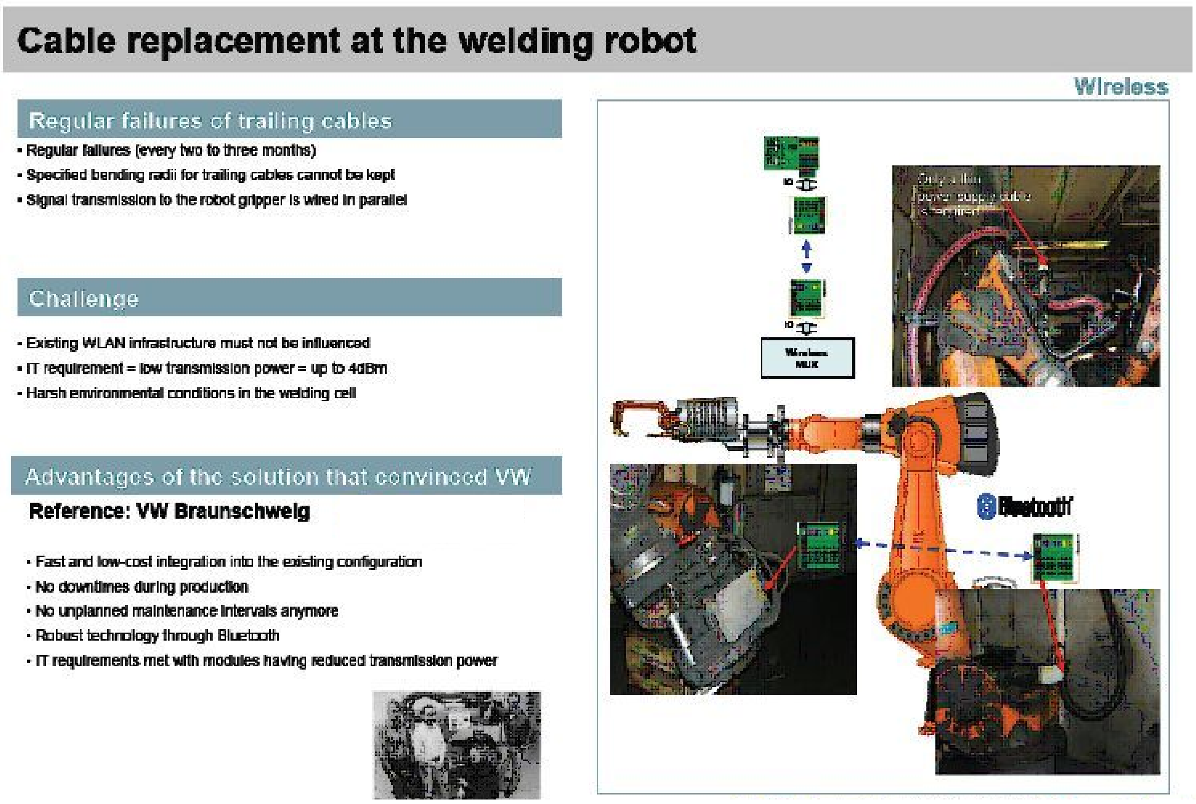



**Figure A.4: Cable replacement at the welding robot**

## A.1.2.2 Rotating tables/storages

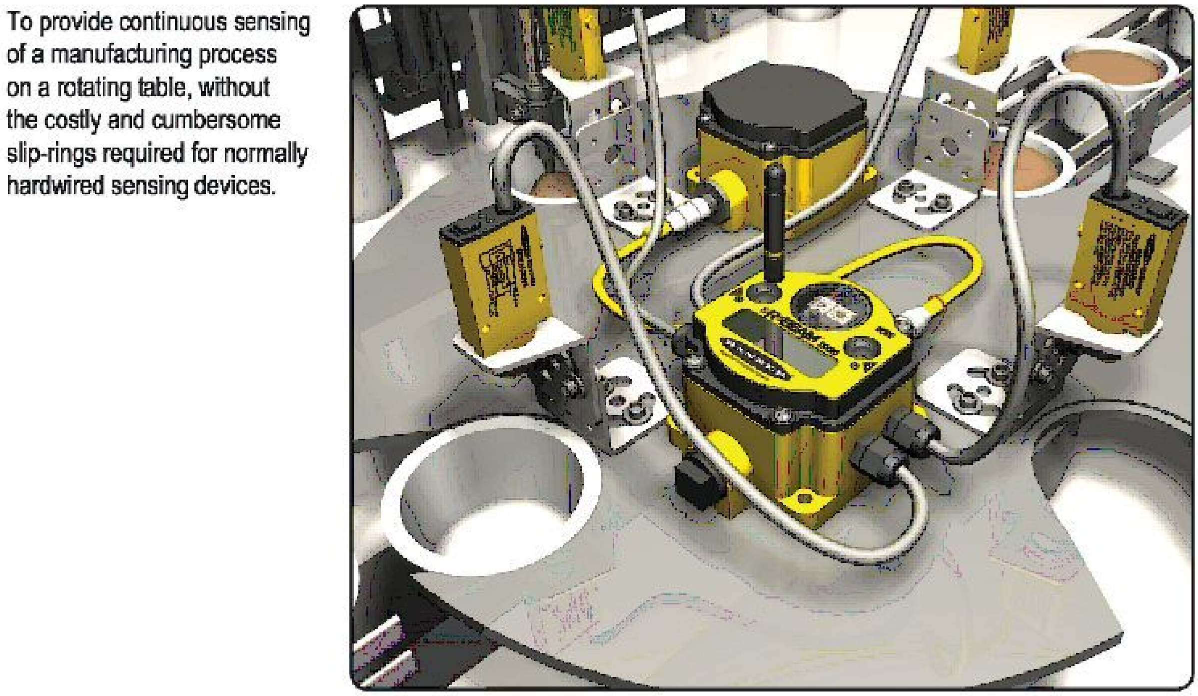



**Figure A.5: Rotating tables/storages**

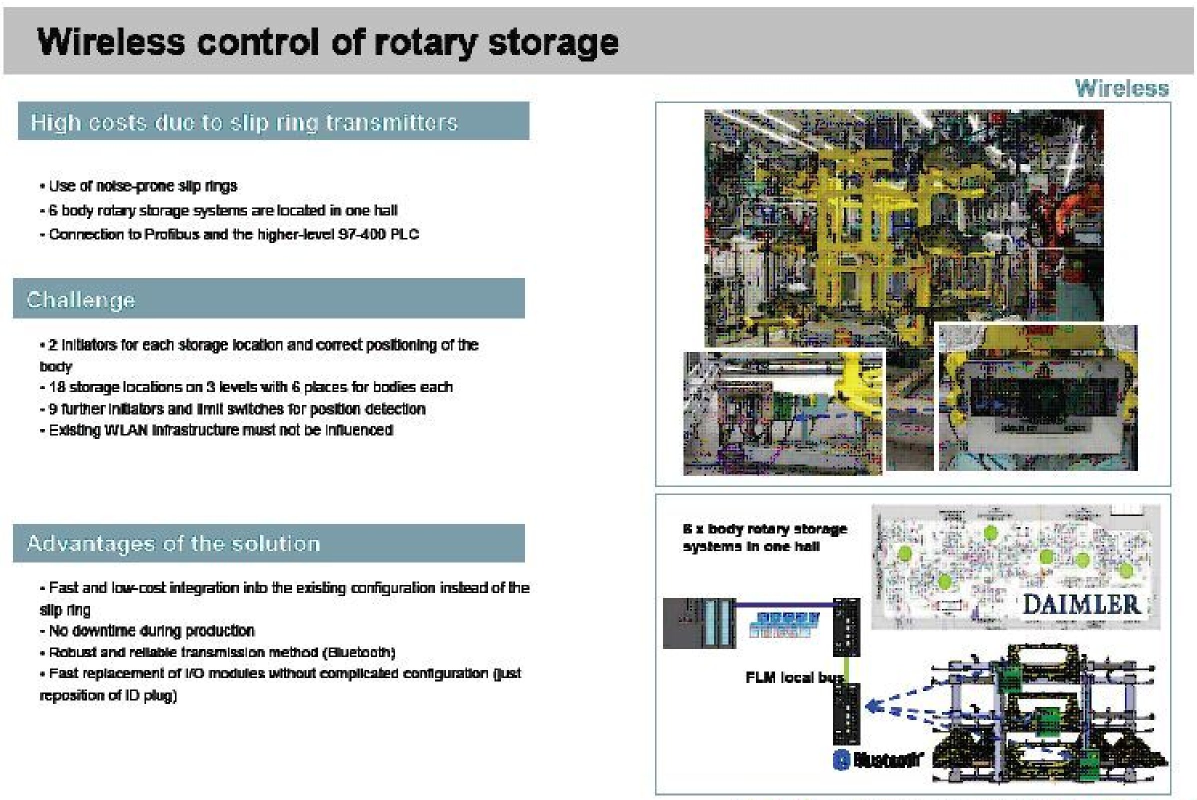
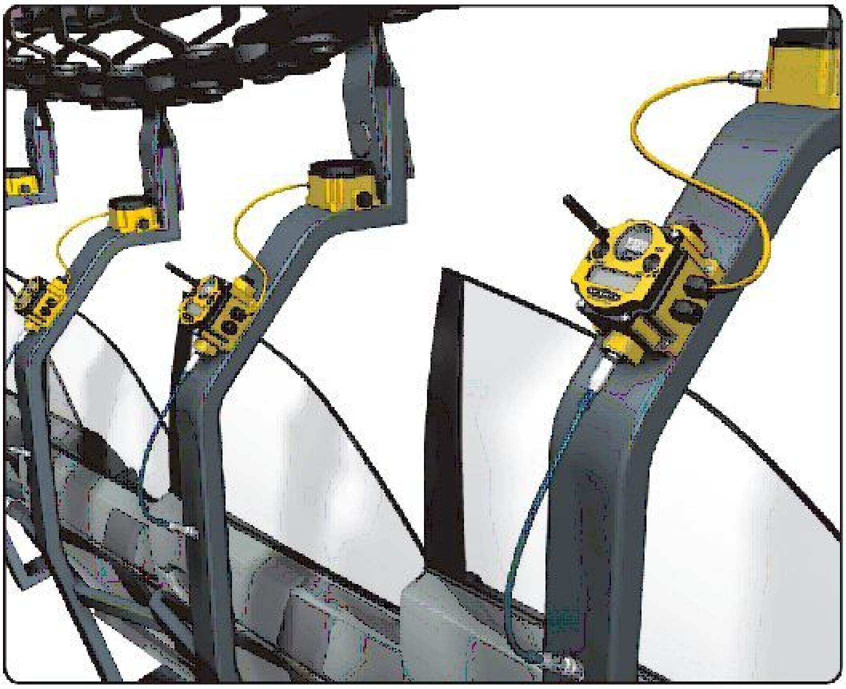



**Figure A.6: Wireless control of rotary storage**

## A.1.2.3 Overhead conveyer systems

Track the presence/absence of an automobile door on an overhead conveyor, without available DC power.

This sensing system is able to withstand conditions in an industrial environment and will function where other wireless technologies are deployed.



The DX80 Nodes on an automotive conveyor communicate with a Gateway located off the chain-driven assembly line.

**Figure A.7: Overhead conveyer systems**

## A.1.2.4 Other moving parts applications

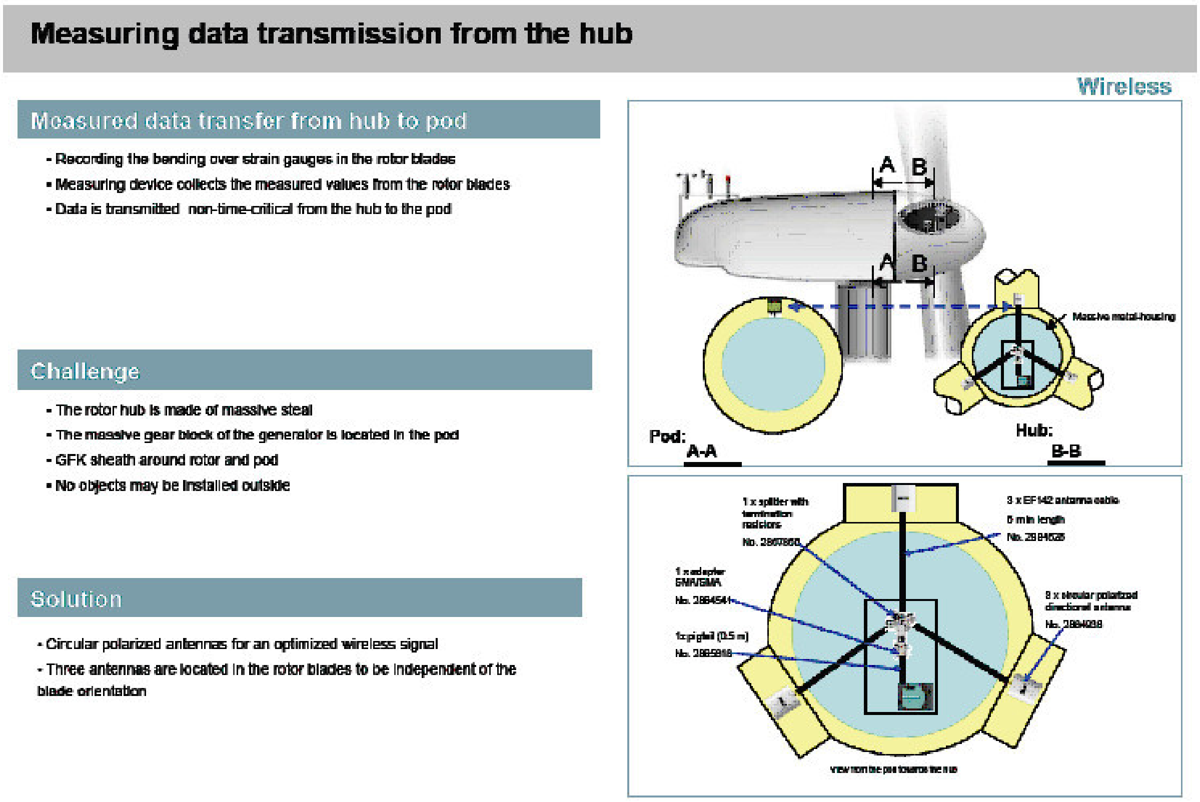



**Figure A.8: Moving parts applications**

### A.1.2.5 Changing tools in an assembly line

No illustration.

## A.1.3 Category B: Reliable and secure applications

Examples are shown in figures A.9 to A.17.

### A.1.3.1 Driverless autonomous transportation systems

The DX80 wireless system works in combination with an AGV (automated guided vehicle) to transfer heavy pallets from various factory workstations to the loading dock, without interrupting the assembly process.

When a pallet is loaded up and ready for shipment, the user can alert the AGV by pressing a button.


The DX80 Gateway and Nodes communicate in a shipping warehouse.

**Figure A.9: Driverless autonomous transportation systems**

### A.1.3.2 High rack warehouse

The transportation vehicle inside a high rack warehouse needs to get a lot of information from the ERP system. In this application an industrial Bluetooth solution exchanges the data between the moving vehicle and the stationary network.

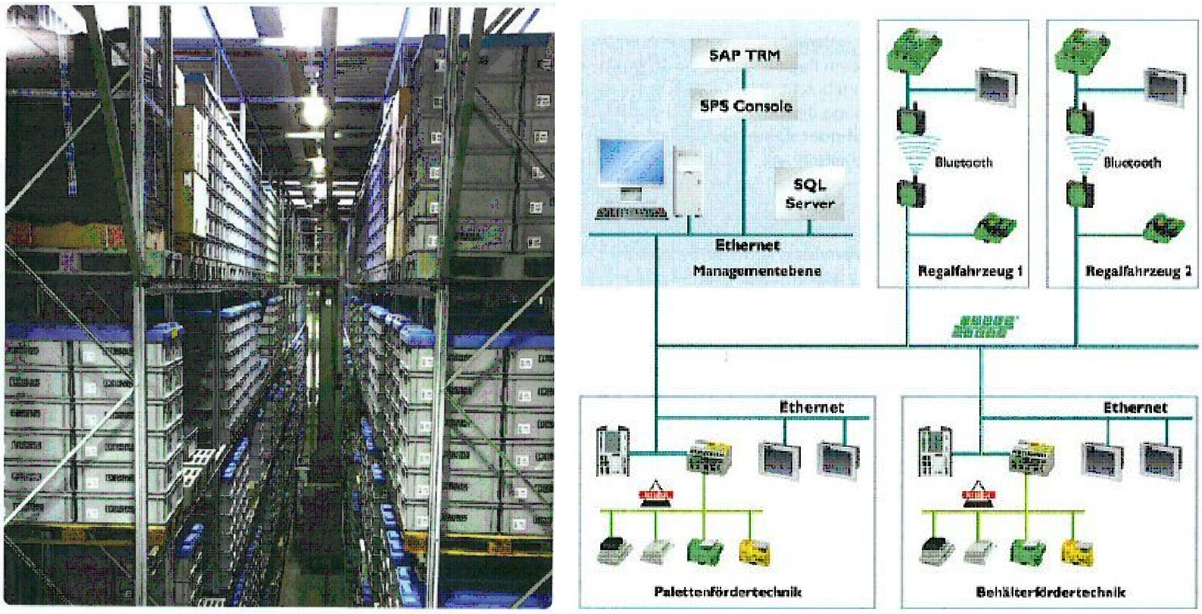



**Figure A.10: High rack warehouse**

## A.1.3.3 Crane control

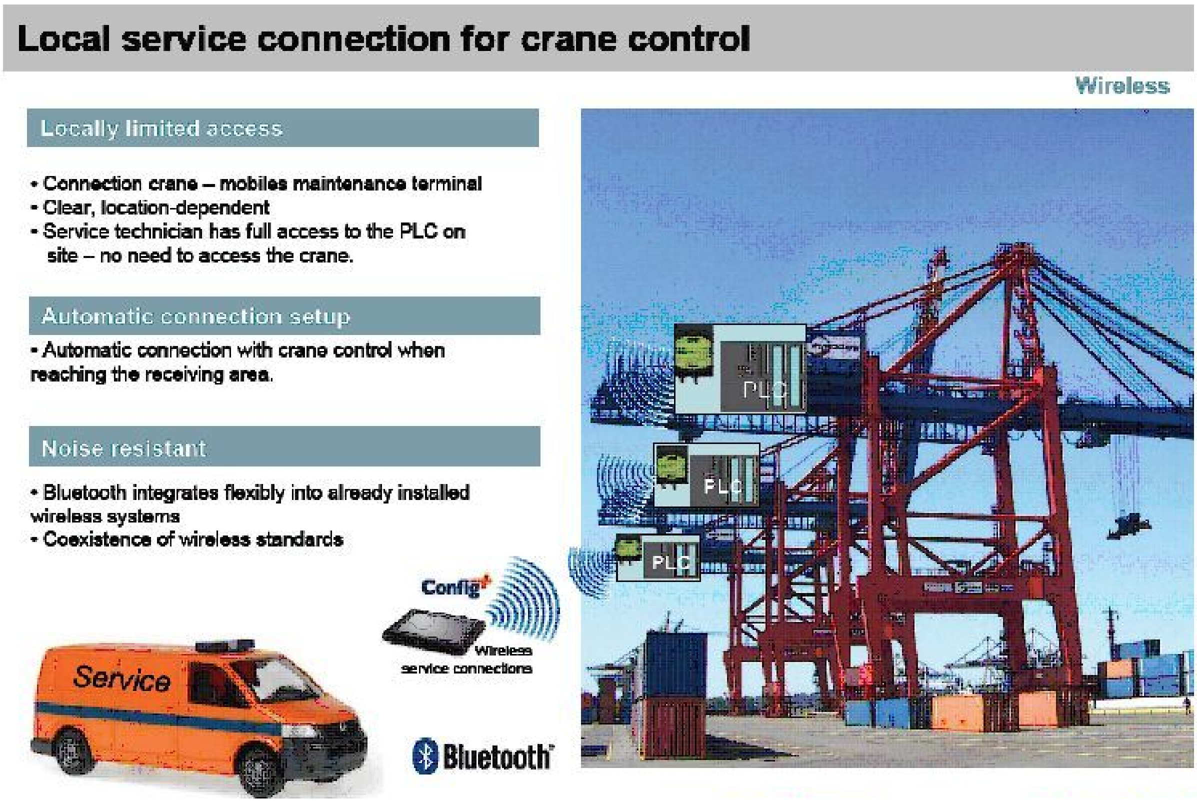



**Figure A.11: Crane control**

In the industry you may find much more barriers than you may imagine. Clean rooms are very difficult to enter - not only for a human, but also for communication cables.

A similar situation is given in the process industry. Very often you find hazardous areas where it is difficult or at least very expensive to install cables. Some examples are given below.

### A.1.3.4 Clean rooms

Liquid level measurements must be gathered in an industry-certified clean room. Retro-fit construction and cabling requires re-certification resulting in significant down time.

The fill levels of components for gel cap manufacturing need to be carefully monitored and logged during production to fulfill FDA requirements.

In addition, the measurements recorded need to coincide with the number of batches produced at the end of each process.

During a gel cap production, the DX80 Nodes installed near each tank communicate readings from QT50U Fill-Level sensors to the Gateway via RF link.

**Figure A.12: Crane control**

### A.1.3.5 Hazardous locations

Example in a Chemical plant could be a Citric Acid Bio-reactor.

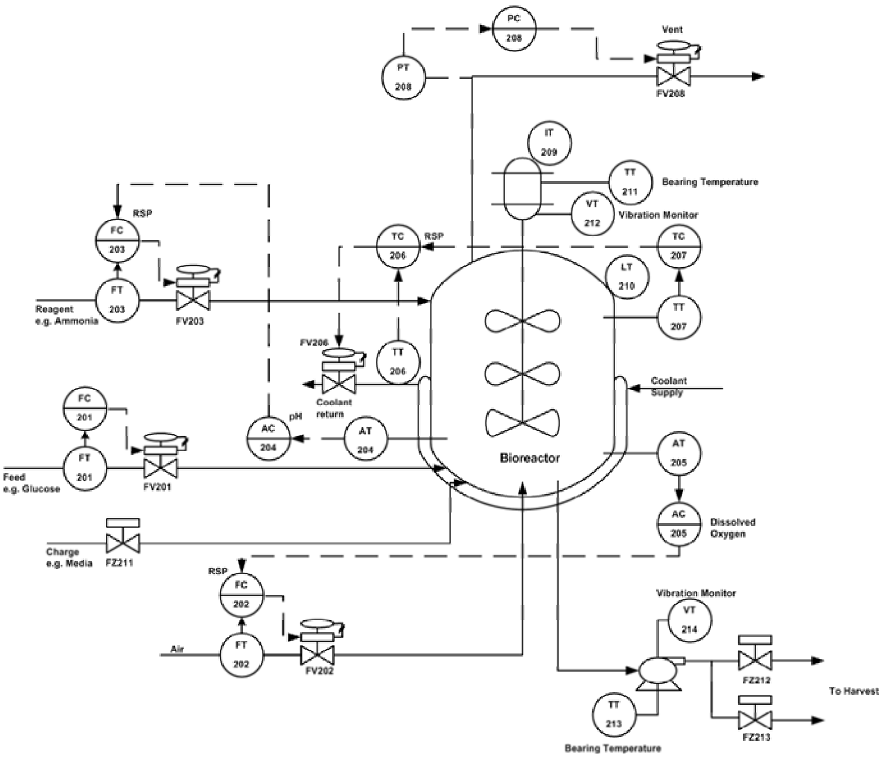
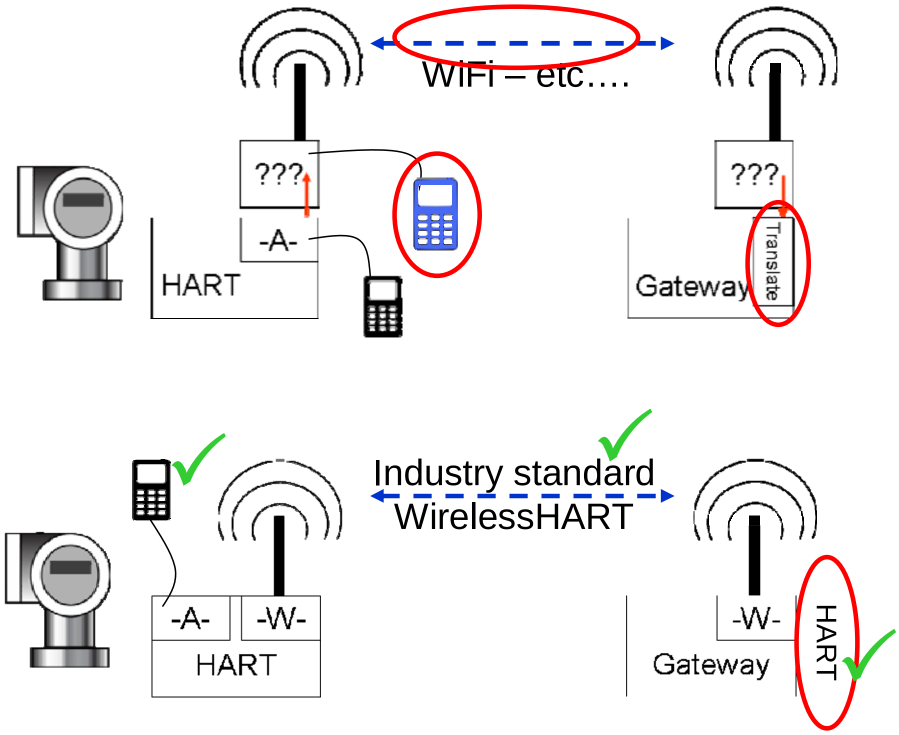



**Figure A.13: P&ID diagram of a boiler control**




NOTE: WirelessHART compliant with EN/IEC 62591 [i.4] can be used in hazardous area.

**Figure A.14: Instrumentation of a hazardous area**

## A.1.3.6 Refinery

**Application**

Natural gas is needed by users in different amounts at different times. The suppliers need to be able to meet seasonal, weekly and hourly requirement fluctuations. Because the supply of natural gas from imported sources is not particularly flexible, it needs to be stored. Natural gas deposits are the best solution for managing the variation between winter and summer demands. Underground storage in cavities hollowed out of the salt domes hold smaller quantities of natural gas, which can be used compensate for short term demand fluctuations. The natural gas storage facility at Lesum near Bremen is one such underground cavern and along with the facility at Harsefeld bei Stade it is used to supply the consumers around Hamburg, Bremen, Bremerhaven and Cuxhaven on cold winter days. The underground storage facility and all the aboveground plant are state-of-the-art and were designed and executed in accordance with the applicable regulations.

The monitoring and control of all the operating procedures in the systems is fully automated by a process control system. The system is automatically switched off and made safe if values go above or below specified limit values. Three artesian wells have been installed to monitor the tightness of the underground storage facility. Their pressure values indicate any leaks in the system. If the pressure exceeds a particular limit, this will indicate a leak.

These pressure values used to be read manually until Hanseatische Messtechnik, responsible for metering and control technology for Mobil Erdöl and Erdgas GmbH, installed three unidirectional radio paths.

**Figure A.15: Refinery industry**

## Application

With the development of oil fields in the Emsland region of Germany, Gaz de France contributes significantly to raw material and energy supply in Germany. The increasing water cut of the oil fields is a problem for oil production west of the Ems - the water content is now around 94 percent. Following separation, this deposit water is transported to the injection pumps. Mixed with fresh water, it is then injected through six water injection wells on the edge of the oil field back into the reservoir rock.

As an important process parameter, the injection pressure at the wells must be monitored continuously. Before converting to wireless technology, the measuring stations for acquiring measured values at the wells were inspected once a day. Now the injection pressure is continuously transmitted via an industrial wireless solution - even when disconnected from the mains. The result is increased safety and efficiency.

In order to transmit the measured values from a well situated on the northern edge of the field to the central injection pump 600 m away, a railroad line had to be crossed.

Before the crude oil is transported to the nearby Holthausen refinery or to the Brögbern pumping station, it must be processed.

**Figure A.16: Gaz production**

# History

| Document history | | |
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| V1.1.1 | August 2011 | Publication |
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