



The use of wireless technology in hazardous areas

by Stephan Schultz



Figure 1: Typical environment for the use of wireless solutions in the process industry

Why radio transmission is becoming increasingly attractive

In our private sphere the use of wireless technology ceased to be unusual some time ago. First the mobile phone took the world by storm with the familiar GSM standard; even serious sceptics now call such a device their own.

However, the wireless transmission of data only became a mass phenomenon with the introduction of WLAN (Wireless Local Area Network) and Bluetooth. The increasing usage of portable computers combined with the wish to communicate over the Internet and to use various computer accessories without the need for cables led to the introduction and standardisation of these technologies. As a result of its compatibility with Ethernet (IEEE 802), it is easy to integrate WLAN into existing network structures. As a consequence this technology has already conquered the office sector and our private sphere. Another representative of this new technology is Bluetooth. This wireless technology was initially used predominantly for communication with accessories related to the PC and the mobile phone. Both WLAN and Bluetooth have in the meantime demonstrated their suitability for everyday use. This situation has resulted in increasing confidence and usage worldwide; a success story. It would therefore seem reasonable to expand the applications to industrial environments. However, there is then the question as to what new challenges this step will bring.

Applications in industrial processes

As with any new technology for radio transmission the question arises for the user as to where and how this new technology can be used cost effectively, in other words: where would the usage of wireless transmission bring sufficient benefits to justify the necessary investment. If it is desired to use wireless transmission as a replacement for cables, then this solution must be compared to the alternative wire-based transmission techniques.

However, wireless transmission also makes it possible to introduce into manufacturing completely new processes that in the past were inconceivable due to the limitations of the wire-based techniques. An example is the usage of portable operator terminals with wireless interfaces for the simplification of maintenance and commissioning. It is therefore sensible to first take a detailed look at the processes in manufacturing so that possible application areas can be identified. In this article the possible application areas in the process industry will be considered in more detail.

› In logistics

In the logistics area the correct and fast acquisition of flows of goods is very important. Many raw materials and products are transported in containers, such as drums, tanks, IBC's, etc. Nowadays these containers are mostly marked with barcodes or RFIDs (Radio Frequency Identifier), so-called RFID-tags. The acquisition of this information automatically leads us to wireless technology. The readers used are mostly hand-held terminals on which a cable restricts operation unnecessarily. The wireless transmission of the data acquired from the portable device to a central management system saves time and costs, and increases reliability due to exact acquisition. Starting from the retail trade, the use of RFIDs as an alternative to barcodes is spreading in the process industry. The advantages of RFID: information can be read even in case of pollution. For example, data can be written to the tags more than once, it is possible to acquire several tags at the same time, etc.

› During installation and maintenance of production systems

Even in this sector the usage of portable devices with a connection to the MES (Manufacturing Execution System) and ERP (Enterprise Resource Planning) promises major advantages in the optimisation of typical processes in production. For example, maintenance orders can be automatically loaded to a portable device for the service personnel. The service engineer can inspect the equipment and enter the results of the inspection, or the repairs made, directly in the portable device (Figure 2). This data is then available in a central database and can be utilised for documentation or billing purposes.

› For operation and monitoring

The same also applies to operation and monitoring of an industrial plant. Portable devices make it possible to read measured values and therefore keep an eye on the state of the production plant on site. At the same time, the personnel in the field have access to information such as maintenance schedules, operating instructions, ATEX certificates, and much more. As a result work can be made considerably more efficient. Camera systems and individual measuring points at some distance, e.g. in pump stations, can be integrated at a low cost with the aid of wireless transmission.

› In process automation

A look at process automation itself reveals the potential offered by the use of wireless transmission. The often complex and costly laying of cables is no longer required. If it is possible to also provide field devices with an independent source of power, then the way is open for the use of wireless transmission in the process industry. In this area there are already a number of promising approaches based on consumption-optimised electronic circuits and alternative sources of power using accumulators, solar cells or recovering energy from vibration, temperature fluctuations, etc. Initial field trials by process control system manufacturers with self-configuring meshed wireless networks have produced an availability of up to 99%. This is without question a respectable result. In the chemical, petrochemical and pharmaceutical industries, however, almost without exception the processes are such that an interruption or error could result in costly losses for the user. Accordingly, the availability of a production plant is one of the most important criteria. For this reason it will be some time before critical signals in control loops are transmitted wirelessly. The integration of individual, difficult to access signals and additional sensors used for the optimisation of processes is, however, already possible today.

› In asset management

Along with the pure process signals for controlling a plant, there are measured signals that are only used for optimisation or preventive maintenance. At the moment primarily the HART transmission technique is used for the transmission of these signals, or sensors are not used at all. The higher level topic of asset management is taking on increasing importance in the process industry. The issue is to always know the state of the production equipment employed in as much detail as possible to anticipate imminent plant failures and to adjust maintenance intervals to actual needs. Without doubt this is a very interesting and appropriate application area for wireless transmission. →

Which technology is the most suitable?

How ever desirable it may be: there is unfortunately no single technical solution to suit all requirements. This situation is also true for the wireless transmission sector. If the possible technologies available on the market are considered in more detail, it is found that each of the candidates has advantages and disadvantages. The majority of these technologies come from the IT sector and were therefore not originally designed for the requirements of industry.

› WLAN 802.11

WLAN is the most suitable for applications involving the usage of portable devices such as barcode scanners or handheld operator terminals. It provides the largest bandwidth (802.11b – 11 Mbit/s or 802.11g – 54 Mbit/s gross data rate) and is designed for the transmission of Ethernet-based protocols. A WLAN network can also pass a user (access client, e. g. a PDA) from one access point to the next without any interruption in transmission. This means the user can move freely around the site without losing the connection to the network.

› Bluetooth 802.15

Bluetooth does not provide the bandwidth of WLAN; however with modern systems transmission rates of up to 2 Mbit/s are possible here. In addition, due to its synchronous communication modes Bluetooth provides a very good basis for real-time applications. Bluetooth is based on the Frequency Hopping Spread Spectrum (FHSS) technique and is therefore significantly less susceptible to interference than WLAN. Networks with up to 8 users can be set up using Bluetooth. Anything beyond this limit will involve increased technical effort. The Bluetooth system consumes less power in operation than WLAN. Due to its characteristics it is excellently suited to the integration of fixed devices, such as terminals or sensors. Both wireless techniques have one feature in common: they are internationally specified ensuring devices from different manufacturers are largely compatible.

› ZigBee 802.15.4

ZigBee enables data to be transmitted at a rate of up to 250 kbit/s and requires significantly less power in operation than Bluetooth or WLAN. The protocol profiles approved up to now by the ZigBee Alliance are tailored to applications in building automation. It is currently unclear in which direction ZigBee will develop. ZigBee forms the basis for the wireless HART protocols and some wireless solutions with self-configuring, meshed wireless networks, so-called wireless sensor networks. To increase the immunity of ZigBee to interference, the frequency hopping technique familiar from Bluetooth is used.



Figure 2: Usage of industrial notebooks for maintenance

In parallel to the standards mentioned, there are a large number of proprietary protocols such as NanoNet, Trusted Wireless, and many others that always have the disadvantage of incompatibility with solutions from other manufacturers.

Standards for application in automation

A whole series of committees and organisations are currently involved in dealing with the problem of insufficient standardisation described above to provide the users and the manufacturers with guidelines. This work is based on the existing standards for WLAN, Bluetooth and ZigBee. For instance at German national level, the organisations VDI/VDE GMA working committee 5.21, ZVEI and NAMUR are involved. The standard VDI/VDE 2185 includes information on the aspects that can be used to evaluate the usage of existing wireless technologies. Since last year in Germany a NAMUR subcommittee has been looking at the subject of wireless automation. The objective of this committee is to formulate requirements on the usage of wireless transmission and to publish guidelines for the user.

At the international level, particularly the ISA (The Instrumentation, Systems and Automation Society of America) with committee SP100 and the HCF (HART Communication Foundation) with a HART Wireless group are addressing the usage of wireless technologies for automation. The specification from the HART Wireless group should be approved at the start of 2007; ISA SP100 is aiming at achieving the middle of 2008.

Simply the number of organisations alone clearly demonstrates the continuously growing interest from users and industry. It can be assumed that the approval of standards will significantly increase the acceptance and the number of wireless solutions.



Figure 3: WLAN access point in flameproof enclosure for use in Zone 1

Peaceful co-existence of the wireless techniques?

The majority of the wireless techniques mentioned use the so-called ISM frequency bands. These frequency bands have the advantage that they are licence-free and can therefore be used at no cost. This situation certainly has a very positive effect on the operating costs. However, this situation also means that different applications must share the frequency band. The standardisation forums are aware of this fact and have already produced technical solutions. For instance, Bluetooth uses an adaptive frequency hopping technique that leaves frequencies out of the hopping scheme at which the transmission suffered interference. As a result it is possible to operate WLAN and Bluetooth side-by-side without interference. This example clearly shows that it is very important to have detailed knowledge of existing networks when planning a wireless network.

Security of the data transmitted

With all its advantages, the introduction of WLAN has at the same time rekindled a primeval fear about the use of wireless transmission. It was initially possible to crack the encryption method used Wired Equipment Privacy (WEP) using very simple means. New encryption methods have, however, proved that adequate protection can be achieved. Unauthorised access to the network is also made more difficult for potential attackers by MAC filters and identification techniques. As WLAN and Bluetooth are often integrated into existing IT structures in organisations, it is important to incorporate them in the overall IT security concept at the related organisation. This means the organisation's IT department must be involved in the planning process.

The frequency hopping technique used for Bluetooth and other wireless techniques provides further protection as the transmission channel between the sender and recipient changes continuously. Eavesdropping without the knowledge of the hopping scheme is almost impossible.

What must be taken into account for wireless transmission in hazardous areas?

Each time a new technology is used, the process industry must ask itself the question: what must be taken into account for usage in hazardous areas? If the subject of wireless transmission is specifically considered, then the following question must be answered: do wireless signals represent an ignition hazard, and if this is the case: what measures must be taken to avert possible hazards?

The question of the 'wireless signal' ignition source is easily answered. Wireless devices emit electromagnetic radiation and this radiation is clearly a possible source of ignition in an explosive atmosphere. Here the risk that an electromagnetic field directly ignites an explosive atmosphere is to be categorised as rather unlikely. Investigations in laboratory conditions have shown that RF sources with powers of several hundred Watts are necessary.

The much greater risk is the induction of currents in metallic objects or inadequately EMI-protected electronic circuits. These currents can result in excessively high temperatures and the formation of sparks. An investigation by the IEEE on the subject of hazards due to electromagnetic radiation in hazardous areas showed that even RF powers of 6 W can become a potential hazard due to induction in metal objects. However, for a long time the standards did not offer any guidelines on this subject. Only at the German national level does a standard currently exist, e.g. in Germany DIN VDE 0848-5 [1]. However, this standard relates to RF sources that are installed outside the hazardous area and that transmit into this area. For RF sources inside the hazardous area, the standard refers to EN 60079-14 'Electrical installation in hazardous areas' [2]. However, here there is only a brief note stating that, during the design of electrical installations, the effects of electromagnetic radiation must be limited to a value that is not hazardous. The user of course then asks himself the question how this requirement is to be implemented in practice.

It is only recently that the draft IEC 60079-0 Table 4 and 56 [3] included useful rules on the use of wireless devices in hazardous areas. The standard provides the user with limits for continuous and pulsed RF signals. These limits relate to frequencies in the frequency range from 10 kHz to 300 GHz (Table 1 and 2).

The limits do not contain information, as is otherwise the case, on classification by zones and the related probability of the occurrence of an explosive atmosphere. This situation makes sense in that an RF signal will not stop at the boundary between two zones.

WLAN, Bluetooth and ZigBee largely use the so-called ISM bands, e.g. at 2.4 GHz, that are only allowed to be used with low transmission powers. Accordingly WLAN access points are limited by RF regulations to 100 mW in the 2.4 GHz band. Bluetooth and ZigBee devices mostly use transmission powers in the range of 10 mW. As a result these transmission frequencies are significantly lower than the limits required in the standard.

However, the so-called antenna gain must also be included in the considerations, as the ignition risk is also defined by the magnitude of the field strength. The antenna gain is a parameter that describes how strongly the power supplied is bundled in a specific direction. The gain is produced by a reduction in the power in other directions; as a result the total power radiated remains →

the same. The antenna gain refers to a reference. If the value is stated in dBi, then this value refers to an isotropic radiator (also called omnidirectional radiator). This is the theoretical model of an antenna that evenly distributes the energy in all directions from a point source. Typical values for rod antennas and directional antennas are between 5 and 9 dBi.

What does this then mean for the user? The values given in the tables must be used in relation to the antenna gain. This requirement can be achieved using a level plan (Table 3).

How do you get the RF into the hazardous area?

Along with the consideration of the permissible limits, there are a number of points that must be taken into account on the installation of RF devices in hazardous areas. The devices currently available on the market have, with few exceptions, no approval for usage in Zone 1. This situation is predominantly due to the development of new devices at very short intervals and the incomplete standardisation. A way out is provided by the installation of existing RF solutions without approval in housings that comply with the type of protection flameproof enclosure 'd' or another suitable type of protection.

The majority of these Ex d enclosures are made of metal resulting in the shielding of the electromagnetic radiation from the antenna. It is therefore clear the antenna cannot be installed inside the housing without additional effort. One solution is to use a pane of glass in the housing and to install a directional antenna inside the housing behind the glass. Trials with such a layout have shown that antennas specially matched to the flameproof enclosure must be used. Otherwise the signal losses are excessive.

The second possibility is the usage of external antennas. However, installation in a hazardous area requires the use of special explosion-protected antennas, mostly with type of protection increased safety 'e' (Figure 3). The background is that in the event of a short circuit between the power supply and the output or input stage in the RF device, no excessively high currents/voltages are allowed to coincide with the explosive atmosphere without protection. Antennas without related protective measures are therefore not allowed to be used.

Planning and service

This section should really be at the start of this article due to its importance. When installing a wireless network, special attention must be paid to planning. Planning starts with the definition of the requirements for the wireless network. This task includes points such as bandwidth, mobility, requirements on real-time signal transmission, the encryption system, requirements on the IT department, etc. During this phase it should also be determined which wireless systems are already in use. It is also important not to forget neighbouring areas.

Apparatus group	IIC	IIB	IIA	I or III
Threshold power P_{th}	2 W	3.5 W	6 W	6 W
	Averaging period 20 μ s	Averaging period 80 μ s	Averaging period 100 μ s	Averaging period 200 μ s

Table 1: Threshold power of radio-frequency for continuous radiation and pulsed radiation whose pulse duration exceed the thermal initiation time (IEC publication 31/635 CDV)

Apparatus group	IIC	IIB	IIA	I or III
Threshold energy Z_{th}	50 μ J	250 μ J	950 μ J	1,500 μ J

Table 2: Threshold energy of pulsed radio-frequency transmission with pulse duration shorter than the thermal initiation time (IEC Publication 31/635 CDV)

	Power budget
RF transmission power of device (100 mW, EIRP)	20 dBm
Connector attenuation	-0,2 dB
Coaxial cable attenuation (RG58, 2 m)	-2 dB
Antenna gain (rod antenna, 5 dBi)	5 dB
Power radiated	22.8 dBm (corresponds to 190 mW)

Table 3: Example level plan for a WLAN 802.11 g transmitter

Using a ground plan it is possible to assess the RF coverage in the area with the aid of planning programmes (Figures 4 and 5). The location and selection of the antenna can then be planned. This planning should then be verified with the aid of a so-called on-site survey, as the ground plan will not contain every detail: it is only necessary to consider the effects of vehicles or temporary containers. This is an on-site inspection using a transportable access point for checking the values determined previously on the computer. In this way it is also possible to determine the bandwidth achieved at the edge of the RF coverage.

Finally, there is the installation and commissioning of the RF system, and a test under real operating conditions to avoid unpleasant surprises. This procedure would appear very expensive, however, it will ensure the system also works correctly and brings the desired process improvement.

Outlook and summary

Wireless transmission is generally expanding and will also conquer the process industry step-by-step. However, here the question of the benefits will always be in the foreground. The benefits must always stand up against conventional connection technology, but wireless transmission also has the potential to establish completely new, more effective processes and to increase quality and safety in manufacturing processes with additional measuring points. The installation of such systems in potentially explosive atmospheres is already possible today and enables the advantages of this technology to also be utilised in these areas.

References

- [1] DIN VDE 0848-5:2001-01 Sicherheit in elektrischen, magnetischen und elektromagnetischen Feldern (Safety in electrical, magnetic and electromagnetic fields)
- [2] IEC/EN 60079-14 Electrical apparatus for explosive gas atmospheres – Part 14: Electrical installations in hazardous areas (other than mines)
- [3] IEC Publication 31/635 CDV 2006-06 Electrical apparatus for explosive atmospheres – Part 0: General requirements

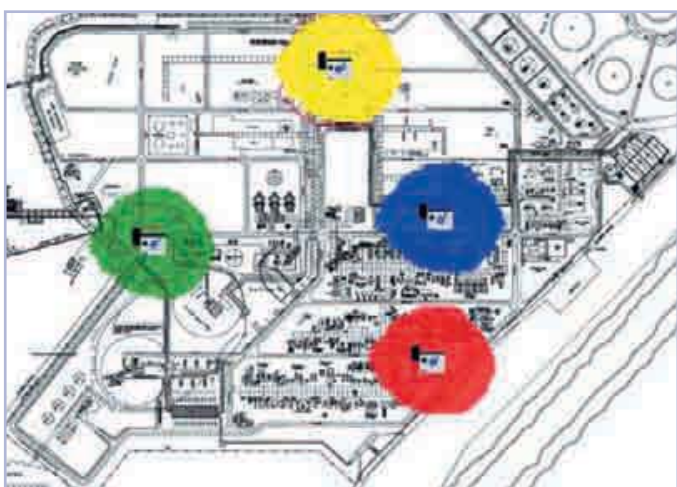


Figure 4: Planning and defining the WLAN frequency bands



Figure 5: Planning the RF coverage using a ground plan