Robust Wireless Communications for Industry 4.0

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Industry 4.0, or *smart industry,* is heralded as a new industrial revolution in which existing systems are networked together to create cyber-physical systems. The first industrial revolution was a convergence of different technologies that enabled engineers to drive the shift from handmade goods to mass manufacturing powered by steam. Today it is a convergence of different technologies, including sensing, communications, and big data processing that are seen as the building blocks of Industry 4.0. By adding connectivity to embedded systems, from the factory floor to the products customers use, and extracting data in real time, it is theorized that efficiency gains of up to 30% can be made. This data could not only optimize the manufacturing process, but could facilitate better business decisions and open the way for new kinds of businesses.

At the base of Industry 4.0 is reliable communications infrastructure. This infrastructure enables decision makers to extract data from machines, factories, and field devices. As noted in the final report of the Industry 4.0 Working Group, it is networking that results in "the convergence of the physical world and the virtual world (cyberspace) in the form of cyber-physical systems" and that "reliable, comprehensive, and high quality communication networks are a key requirement for Industry 4.0."

Sub-GHz wireless connectivity has already enabled automated utility metering and remote sensing, such as structural monitoring. Wireless devices, often battery powered, use sensors to measure and quantify the physical world and send this data to a collector node or gateway where it may be sent to the cloud for aggregation and processing. Wireless solutions are making inroads in factory automation, and shipments of wireless devices are expected to increase to meet the requirements for civil works, agriculture, and the environment, as well as energy production and distribution.

When designing a wireless system, engineers consider many factors. As every engineer will recall from Friis's transmission equation to increase the range one can change a number of parameters, such as increasing the transmit power or receive sensitivity or both. However, regulations restrict the maximum transmit power, and components such as high power antennas and external LNAs may add significantly to the cost of a system. Therefore, when choosing a wireless receiver, the first specification engineers look to is the receive sensitivity. However, sensitivity alone does not tell the full story.

For connectivity within industrial ecosystems, reliable radio connections are critical. Maintaining reliable communications can be a challenge in an increasing hostile RF environment, particularly in the industrial space. The unlicensed industrial, scientific, and medical (ISM) radio band continues to see a growing number of users with hundreds of millions of active devices deployed since its introduction in 1985. There are several potential sources of interference these radios must contend with, from unintentional RF radiators to other active RF devices that may be operating in the same band, often using proprietary protocols. Interference can severely degrade communications range. Larger, denser networks also mean more nodes transmitting in close proximity and therefore greater need for better receive performance. Resilience to interferers is extremely desirable. It can reduce the required number of repeater nodes and enable more endpoints per gateway. This results in more robust network coverage with fewer black spots. With reliable radio connections, fewer packets are lost, resulting in fewer packet retransmissions and an overall more efficient system.

To understand a receiver's performance, we must turn to the data sheet and examine the selectivity and blocking figures. For a radio receiver, the RF selectivity is its ability to differentiate the desired signal from unwanted signal sources transmitting in other channels. Adjacent channel rejection (ACR) describes a receiver's ability to receive a wanted signal in one channel when an interfering signal is active in a channel that's spacing is one channel lower or greater than it. The alternate channel is one channel more removed from the adjacent channel. The greater the rejection, the better the receiver performance in the presence of interferers. Blocking refers to interferers further away and out of the receiver's band. Even several MHz away, high power interferers can degrade communications and result in lost packets.

One element of achieving good blocking and selectivity figures is reducing phase noise in the RF system. Phase noise, the noise introduced by short-term phase fluctuations in a signal, can be seen as sidebands that spread out from the wanted signal in the frequency domain. Phase noise is usually measured relative to the carrier, in dBc/Hz—that is, the noise power in a 1 Hz bandwidth at a specified offset from the carrier. This noise acts to degrade the receiver performance by affecting reciprocal mixing, as shown in Figure 1, and by raising the noise floor. In a receiver, when the wanted signal is downconverted to the intermediate frequency used for signal processing, a tail of an interferer can be mixed and cannot be subsequently filtered out.

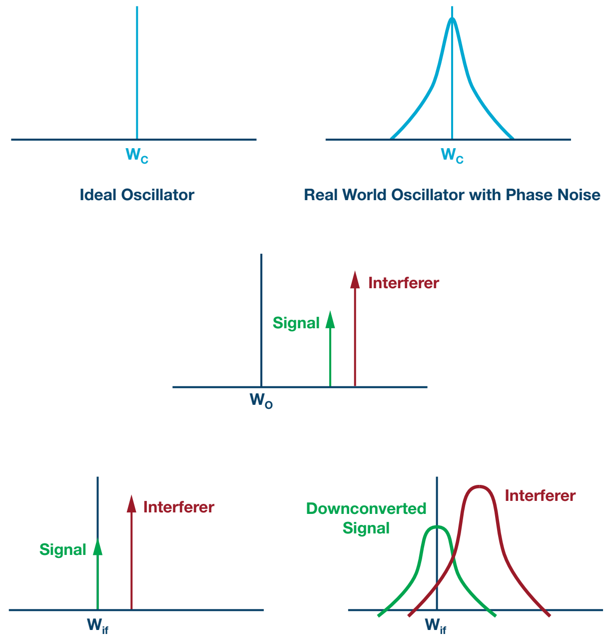

Figure 1. Phase noise basic theory.

The front-end linearity of a receiver impacts resilience to nearby high power interferers. For sub-1 GHz radio networks, such an interferer may be LTE. For a measure of linearity in the receiver, we turn to the input third-order intercept (IIP3). This is measured by inserting two tones into the receive chain and measuring the third-order intermodulation product that appears at 3× the frequency spacing of the input tones.

The ADF7030-1 from Analog Devices seeks to address the challenge of reliable connectivity. The ADF7030-1 is a sub-GHz, fully integrated radio transceiver. It is suitable for applications that operate in the ISM, SRD, and licensed frequency bands at 169.4 MHz to 169.6 MHz, 426 MHz to 470 MHz, and 863 MHz to 960 MHz. It supports standards-based protocols like IEEE802.15.4g, while also providing flexibility to support a wide range of proprietary protocols. The highly configurable, low intermediate frequency (IF) receiver supports a large range of receiver channel bandwidths from 2.6 kHz to 738 kHz. This range of receiver channel bandwidths allows the ADF7030-1 to support ultranarrow-band, narrow-band, and wideband channel spacing. It is designed to provide best-in-class blocking and provides excellent sensitivity.

The high performance, low power analog front end (AFE), utilized by the ADF7030-1, uses high dynamic range ADCs, analog complex antialiasing filtering with QEC, and digital channel filtering to remove unwanted signals in the receive chain. Using these techniques, the ADF7030-1 is able to achieve up to 102 dB blocking at ±20 MHz offset and up to 66 dB adjacent channel rejection.

To maintain high performance receive performance across all supported signal bandwidths and frequency bands, the ADF7030-1 employs a reconfigurable VLIF receiver architecture with dual-band LO paths. This allows the ADF7030-1 to support a wide range of applications.

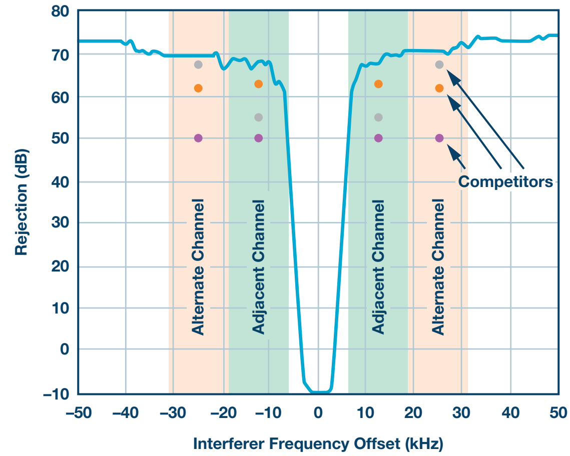

Figure 2. ADF7030-1 ACR vs. competitors.

The ADF7030-1 offers best-in-class rejection performance and has an IIP3 value of –8.5 dBm at max receiver gain. This gives end users the confidence that they will meet regulatory requirements and removes the need for costly external components such as SAW filters. An example of one such standard is ETSI Class 1 with 25 kHz channel spacing. This requires 60 dB adjacent channel rejection and 84 dB selectivity. The ADF7030-1 exceeds these requirements by a significant margin.

Industry 4.0 challenges engineers to develop innovative and compelling solutions to enable the next generation of connected and smart devices. Analog Devices is an industry leader when it comes to managing the real-life environmental effects on communications systems and has been designing reliable solutions to connect the physical and digital worlds for over 50 years. Ensuring robust and reliable communications is key to rolling out the connected world to service the Internet of Things and services envisioned by Industry 4.0.

About the Author

Sean O'Connell graduated from University College Cork with a degree in electrical and electronic engineering. He works as a product applications engineer in the IoT Solutions and Security Group, supporting low power RF transceivers; for example ADF7030-1 and ADI SmartMesh®, a complete ready-to-deploy mesh networking solution. He can be reached at *sean.oconnell@analog.com*.

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