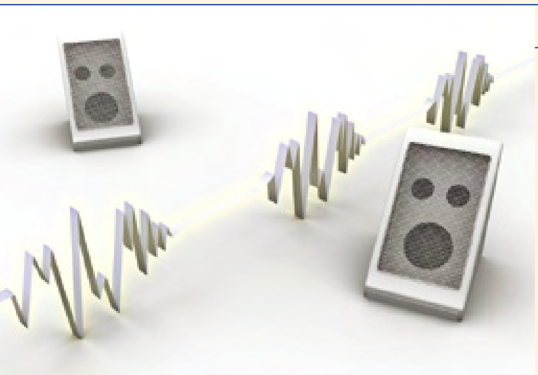
Software-Defined Radio architecture for communications test

By Spencer Stock and Ron Harrison



It seems that a new wireless or communications standard is introduced each day. Although this is not true, the list of wireless and communications standards is rapidly growing (see Figure 1). In the last few years, more and more standards deal with the increasing need and demand for data. We now face a log jam *of standards. Just a few years ago, a single wireless technology per device was sufficient. Now, due to the number of standards existing at the same time, devices must implement multiple standards to compete by providing seamless operation across different networks and for differing applications. In this article, Spencer and Ron explain the advantages of devices that support multiple communications standards, and where these technologies are taking the industry.*

In addition to the demand for multiple wireless standards, industry is driven by the ever-present pressure to quickly get new products to market and research and design are outpacing test. Manufacturers release ZigBee and 802.11n devices before the standards are complete. Predefined standard test systems from stand alone instrument manufacturers no longer exist. This is attributable to the fact that the traditional cycle of releasing a wireless standard, prototyping devices among lead users, and developing test equipment for mass commercial use is too time consuming.

The demand for devices that incorporate multiple standards and the pressure to release new products before the competition are two major reasons many engineers work with more than one wireless and communications standard. In fact, the data gathered by a National Instruments Instruments Study survey in Figure 2 illustrates that almost two-thirds of engineers designing and testing devices with wireless and communications functionality use more than one standard, with the following percentage breakdown:

- 37 percent use one standard
- 30 percent use two to three standards
- 33 percent use four or more standards

Traditionally, you would need a separate stand alone instrument for every communications standard to be tested. Each instrument has vendor-defined functionality for a particular standard. The communications measurement algorithms for the standards exist as firmware running on the embedded processor in each instrument, which means they are not user-accessible or customizable. Purchasing a new stand alone instrument for each standard that you need to test is not productive or cost-effective. This is pushing engineers to seek flexible, *out-of-the-box* solutions.

Flexible software-defined communications test

One way to keep stride with wireless and communications advances is through software. You can take a software-defined approach to instrumentation by using coding and

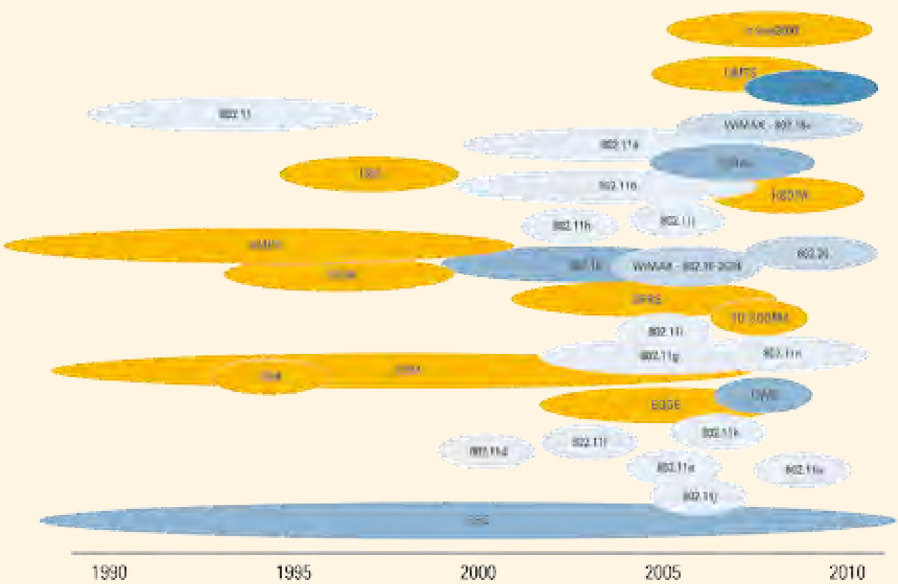


Figure 1

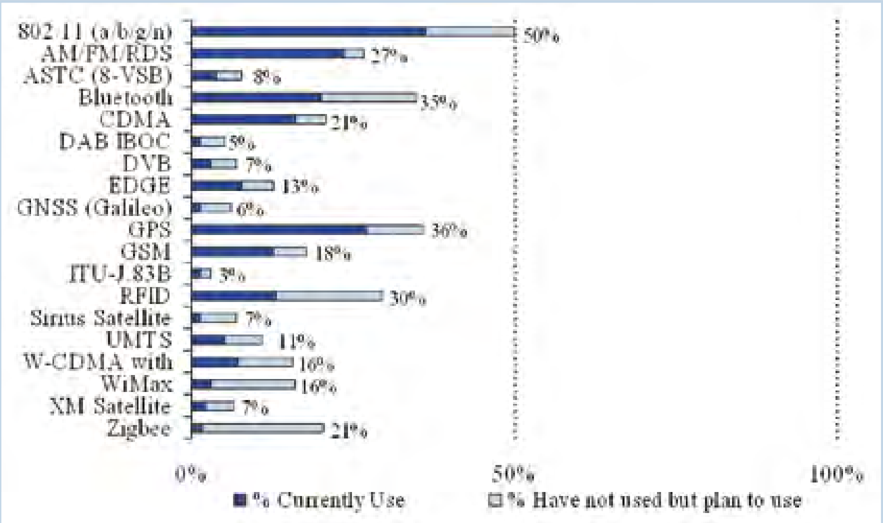


Figure 2

modulation software to generate and measure signals through modular, general-purpose RF instrumentation. This Software-Defined Radio (SDR) approach to test is completely application-driven and user-defined. You can use it to leverage the software modeling and simulation software used in research and design for test and measurement. The Department of Defense already supports this strategy.

"For the military, SDR is a transformational technology that allows the development of a truly interoperable family of radios that can communicate in any theater of operation with any allied force at any time," said Colonel Steven MacLaird, director of the Joint Systems Program and program manager for the JTRS Joint Program (SDR Forum, August 2003).

A typical communications system

By stepping through a simplified functional block diagram of a typical communications system, you can see how to combine communications software with modular, general-purpose RF instrumentation to create a test system that supports multiple standards. Figure 3 represents the major functional blocks in a typical communications system. You can use these blocks for source coding, channel coding, modulation, and upconversion on the transmit side, and the reverse of this process on the receive side. A real-world communication link contains a physical channel across which the transmission occurs. Physical channel examples include air (wireless), fiber optic, and copper.

Source coding and decoding

The primary function of source coding is to represent your message in as few bits as possible to minimize resources. Source coding is similar to data compression; the smaller the message, the faster the transmission time, which translates into more efficient use of precious resources and spectrum. With source coding, you can send more information using the same bandwidth. Some of the more common source coding algorithms include jpeg compression, zip (a combination of the LZ77 and Huffman coding algorithms), MP3 (part of MPEG-1 for sound and music compression), and MPEG-2 (used in DVDs).

Channel coding and decoding

Unlike source coding, channel coding can add bits to the data, which increases the message size. Added or reworked bits ensure that the original message can better withstand the

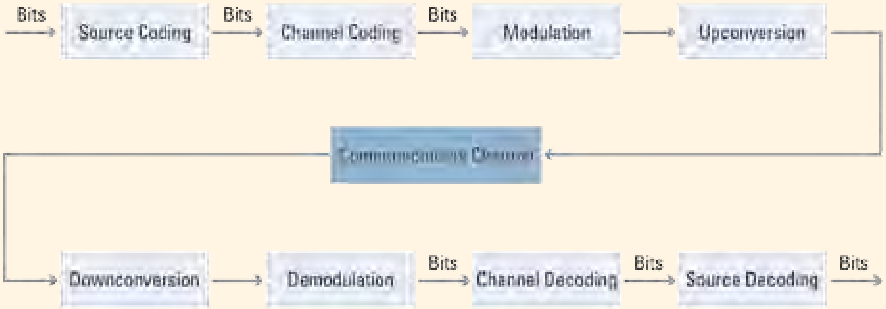


Figure 3

effects of any channel impairments, including noise and fading, for proper decoding to obtain the original transmitted message. Many channel coding algorithms balance the need to correctly encode and transmit data while minimizing message size.

Modulation and demodulation

Modulation is the process of varying one or more properties (amplitude, frequency, and/or phase) of an electromagnetic wave or signal. You can use modulation to transmit information that originates at a low frequency signal to a signal operating at a higher frequency. You may wonder why you would want to transmit at a higher frequency as opposed to a lower frequency. Transmitting a baseband audio signal (from 20 Hz to 20 kHz) in a wireless fashion would require an antenna, power source, and electronic equipment of substantial proportions, which is impractical because of the large wavelength that is inversely proportional to the frequency. Therefore, if you transmit this same signal at a higher frequency, the wavelength becomes smaller, and you can reduce the size of the equipment and the amount of power you need. This fact signifies the prevalence and importance of modulation. With modulation, you can piggyback your baseband signal on a higher-frequency signal. The lower-frequency signal that contains the information or message you want to transmit is the modulating signal. The higher-frequency signal is referred to as the carrier signal because it *carries* the baseband information. The resulting combined signal is called the modulated carrier signal.

You also can use modulation when you want several signals to share the same channel, or if you want to transmit more information without increasing the signal bandwidth. You achieve more efficient bandwidth use because more information can be carried in the same amount of space. You can choose a specific modulation format depending on the application and the amount of data you need to transmit. In addition to standard modulation formats, by performing modulation and demodulation in software, you can develop custom formats, which is particularly useful for proprietary and/or military applications that require custom formats.

Upconversion and downconversion

You can use an upconverter and downconverter to shift an input frequency either up or down, respectively. The primary component of upconversion and downconversion is a device called a mixer. Mixers *multiply* two signals with different frequencies to produce a sum and difference signal.

Figure 4 illustrates the earlier functional block diagram of a typical communications system with National Instruments LabVIEW graphical code. The functions are for source coding, channel coding, modulation, and upconversion on the transmit side, and downconversion, demodulation, channel decoding, and source decoding on the receiver side. The software is particularly suited for a PXI system, which provides the modular, general-purpose RF instrumentation required to both generate/upconvert and downconvert/acquire the communications signals.

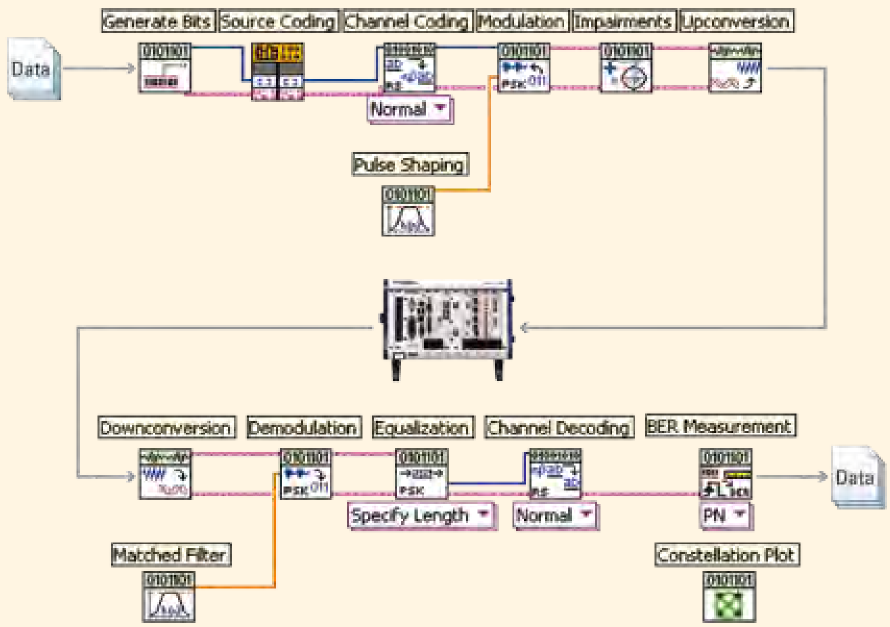


Figure 4

PXI - An ideal platform for software-defined communications test

There are many reasons why the PXI platform is ideal for software-defined communications test. Most importantly, it is PC-based. The functionality of PXI instruments is defined in software so a single PXI RF instrument can test multiple communications standards by simply changing the software running on the system controller. PXI controllers employing the latest dual-core processors can easily process the most complex communications algorithms. An example of a complete PXI test platform is shown in Figure 5.

As communications standards continue to scale the amount of data transferred, it is important to base a communications test platform on a high-throughput bus to transfer the data. PXI is based on the PCI and PCI Express buses, providing up to 6 GBps of system bandwidth and up to 2 GBps of bandwidth to a single instrument. With this throughput, you can use PXI to perform long-duration recording of communications signals for off-line analysis and the playback of previously-recorded or simulated signals.

Also, with the modular nature of PXI, you can upgrade a single component of a system. For example, you can increase the performance of all of the instruments in a PXI system by upgrading to a controller with a higher-performance processor. This type of upgrade is not possible with stand alone instruments, where the embedded processor is not user-accessible or upgradeable. Moreover, because PXI is a multivendor platform, the modular components of a system can come

Figure 5

from multiple vendors. You are not locked into a single vendor, and, because all PXI products must adhere to the PXI hard-ware and software specifications, inter-operability between different vendors is guaranteed.

Most systems that test communications must also test other device functionality and include other instruments, such as digital multimeters (DMMs), programmable power supplies, and switching. The PXI platform is general purpose and offers instruments for most applications and measurements. More than 1,000 PXI modules are available from the more than 68 members of the PXI Systems Alliance (PXISA).

The future of software-defined communications test

The demand for devices that support multiple communications standards and the pressure to quickly get new products to market will only continue to increase. More and more engineers will need to move to more flexible, scalable and rapid development test platforms. Software-defined communications test with the modular PXI platform is an approach with the flexibility to ensure that test engineers meet these requirements both now and in the future. PXI

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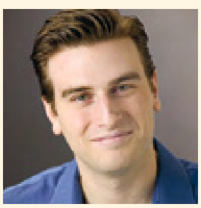
***Spencer Stock** is a product marketing manager for PXI at National Instruments. He is currently serving as the co-marketing chair of the PXI Systems Alliance. Spencer began with National Instruments in 2002. He holds a Bachelor's degree in Electrical Engineering from the University of Nebraska.*



***Ron Harrison** is the product marketing manager for National Instruments RF and communications products. His previous role at National Instruments involved marketing automated test software including NI TestStand. Ron received a Bachelor's degree in Computer Engineering, with a major in RF and communications, from the University of Waterloo, Ontario.*

National Instruments

11500 N. Mopac Expressway • Austin, TX 78759

Tel: (888) 280-7645 • Fax: 512-683-8411

E-mail: spencer.stock@ni.com, ron.harrison@ni.com

Website: www.ni.com