

# basics of Design

## Virtual RF Design and Testing

**Louis E. Frenzel**  
Communications/  
Networking Editor

### Software and virtual instrumentation meet the design and testing challenge of growing wireless adoption.

**W**ireless ubiquity—even if we aren't quite there yet, we soon will be. The number of wireless technologies developed and implemented over the past decade is astonishing. Cell phones definitely top the list of key applications, but there are so many others. In fact, most of these new wireless methods are short-range technologies designed to replace cables and provide greater mobility and freedom.

All of these wireless technologies can be easily implemented and incorporated into almost any product thanks to a slew of wireless standards and low-cost wireless IC transceivers to meet them. As a result, almost all engineers today face the prospect of having to build wireless capability into their products.

Most engineers, including EEs, typically aren't trained in wireless theory or practice. So, the challenge is to design and test such products successfully under a barrage of difficult conditions. While many designs are made easy by implementing a manufacturer's reference design for a given chip set, the real work begins with the tests and measurements that must be made to conclude a successful

design and get it through manufacturing. A growing number of software simulation and testing products now makes that possible by letting designers design and then test quickly and easily.

### An Embarrassment of Wireless Riches

Today's designers can expect to encounter a host of wireless technologies. Figure 1 shows the most popular technologies and how their range and data rates compare.

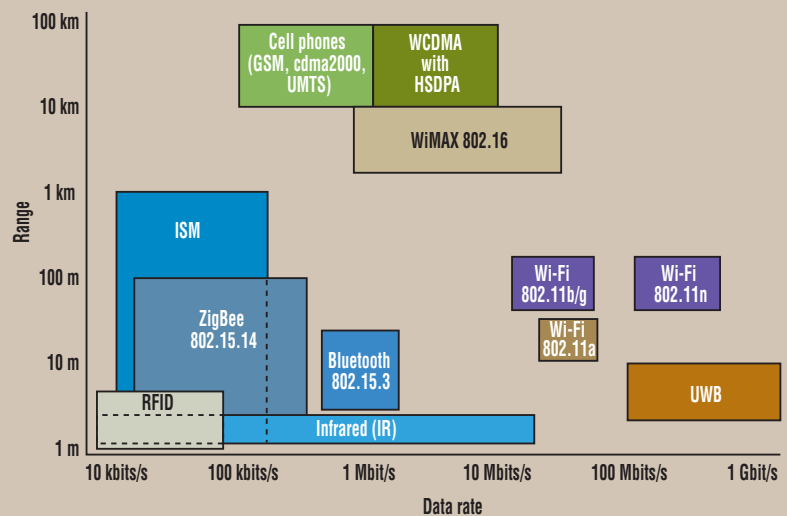
**Bluetooth:** By far, Bluetooth is the most widely used wireless format. This 2.4-GHz personal-area networking (PAN) technology can be found in cable-free cell-phone headsets, PC-to-cell-phone connections, and PC peripheral connections. It

offers a data rate up to 3 Mbps at a typical range of 10 m.

**Cellular telephones:** Cell phones represent the largest wireless category. GSM/GPRS/EDGE and cdma2000 standards dominate the field, which is evolving into various 3G technologies like UMTS, WCDMA, and HSDPA, as well as 1xEV-DO and 1xEV-DV versions of cdma2000. 4G orthogonal frequency-division multiplexing (OFDM) systems are in development.

**Digital Radio:** Satellite radios operating in the 2.3-GHz band are commonly built into new cars and trucks, and many portable units are now available. HD Radio, a digital technology that works in the existing AM and FM bands, is now on the air, and more receivers are becoming available.

Range Versus Data Rate: Common Wireless Technologies



1. When comparing range and data rate among popular wireless technologies, UWB dominates the high data-rate range—but at short range.

**ISM Wireless:** Unlicensed wireless applications can take advantage of the industrial, scientific, and medical (ISM) bands. Common frequencies and applications include 315 MHz for garage-door openers and remote keyless entry, 433 MHz for remote temperature sensors, and 915 MHz for telemetry.

**RFID:** Radio-frequency identification (RFID) is a growing wireless technology that provides a unique radio-based barcode replacement. It also provides an improved way to track and identify any item that is stored or transported. Passive RFID tags require no power other than the power they receive from their reader or interrogator. Active tags use tiny batteries to extend range.

**Ultra-Wideband (UWB):** This really wideband technology operates in the 3.1- to 10.6-GHz band. It uses direct-sequence coded monopulses or OFDM to transmit data at rates from 100 to 500 Mb/s over a range of about 2 to 10 m. It's ideal for streaming video, but wireless USB ports are the initial target.

**Wi-Fi:** Also known by its IEEE standard number 802.11, Wi-Fi was developed for wireless local-area networks (WLANs). It's a real hit with the laptop crowd, as people can tap into their e-mail via public hotspots. The basic 11b standard provides a data rate of up to 11 Mb/s up to 100 m in the 2.4-GHz band. The 11g standard boosts the rate to 54 Mb/s in the 2.4-GHz band. 11a also provides a data rate to 54 Mb/s in the 5.8-MHz range. The forthcoming 11n standard promises a data rate exceeding 100 Mb/s and as high as 600 Mb/s using spatial division multiplexing and multiple-input/multiple-output (MIMO) antenna technology.

**WiMAX:** The IEEE 802.16 wireless broadband standard targets metropolitan-area networks (MANs). It's still new, but it promises consumer wireless broadband services and low-cost cell-site back-haul as well as wireless Voice over Internet

Protocol (VoIP) phones. A new mobile version, 16e, may compete with Wi-Fi hot spots.

**ZigBee:** The IEEE 802.15.4 standard for short-range monitoring and control applications in buildings, factories, and homes offers a low data rate of 250 kb/s in the 2.4-GHz band. But it also provides highly reliable telemetry and control in hundreds of applications. A key feature is its ability to automatically create ad hoc mesh networks. Its primary application target is wireless sensor networks for monitoring everything.

## The Wireless Testing Challenge

The biggest issue in wireless is that testing time has become as much as 70% of the cost of an RF product as engineers test for certification, Federal Communications Commission compliance, and electromagnetic-compatibility and electromagnetic-interference mitigation. Another key challenge is keeping up with standards revisions, emerging standards, or testing to multiple standards.

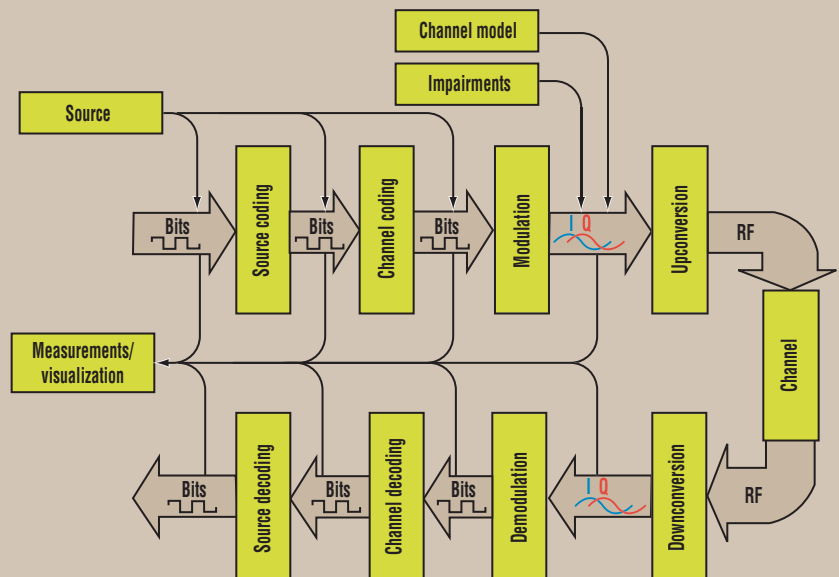
Furthermore, as IC manufacturers include more features in their

chips, test time rises proportionally. For standard commercial or industrial products, total wireless test time may be as much as 2.5 hours. It can approach eight hours for testing to military standards. A new and better approach is needed.

## Traditional Versus a Virtual Instrumentation Approach

Traditional test equipment packages a limited number of measurements and typically a single protocol solution per box. With multiple protocols per product, which is the norm today, multiple separate test boxes will be needed, not to mention the usual oscilloscope, spectrum analyzer, digital multimeter, and other traditional test instruments needed for the mixed-signal testing still required.

An alternate approach uses virtual instrumentation (VI), which combines a computer, software, and modular hardware in a chassis with a PXI bus or similar bus. The instruments are truly software-defined. The modular hardware makes them fast and easy to upgrade and expand, and it's also



2. Designers can use mathematical equations, software libraries, or a graphical programming language to build wireless systems that will look like the system shown here.

easy to include new protocols.

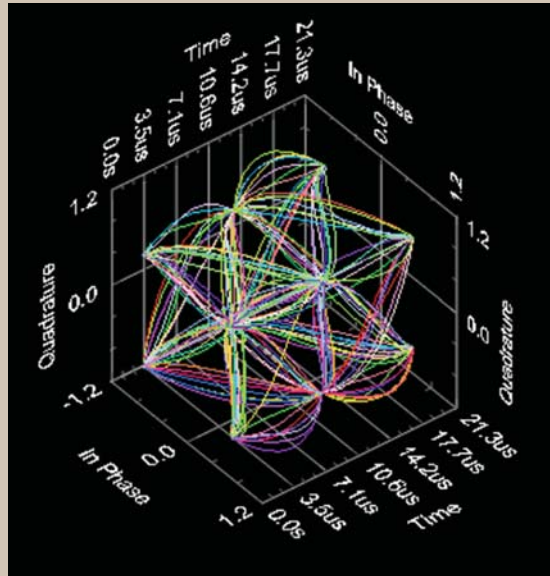
The VI approach provides the measurement precision of traditional equipment while adding the flexibility of modular plug-in cards and quickly configurable software. VI's lower cost and ability to customize the test setup to the product make it worth considering. With today's continuously changing standards, flexibility is a key to any instrumentation investment.

## Simulation Speeds Test Design

A variety of available wireless design and test programs lets engineers develop simulations and mathematical models of their test system. Some software starts with the math equations detailing the desired processing, while other software can be built from programming libraries. Another kind of simulation product is the graphical data-flow programming language, National Instruments' LabVIEW. Designers can use such tools to create block diagrams to build a simulation model. The overall goal is to simulate the test system before you build it.

Figure 2 shows just what an engineer can build on screen. A digital signal to be transmitted can be subjected to source coding, channel coding such as Reed Solomon, Golay, Hamming, Convolutional or BCH, modulation, and upconversion to the final transmit frequency. Modulation (and demodulation) options abound with AM, ASK, PAM, FM, FSK, MSK, GMSK, 4QAM through 256 QAM, PM, BPSK, QPSK, OQPSK, DQPSK, and many others.

The simulation also can include the simulation of channel impairments, such as additive white Gaussian noise (AWGN), IQ gain imbal-



3. Many simulation programs offer a variety of graphical outputs so engineers can visualize all of the aspects of their designs and its performance.

ance, quadrature skew, phase noise, dc offset, fading, and other traditionally encountered effects. The received signal is then downconverted, demodulated, and decoded to recover the original signal.

The software's analysis and visualization options are critical. Designers can look at Trellis diagrams, constellation plots, and 2D or 3D Eye diagrams all on the PC screen (Fig. 3). Common modulation analysis functions include bit error rate (BER), modulation error ratio, and error vector magnitude (EVM).

Engineers not only can design and assess standard formats, they also can explore the possibilities of other unique approaches to a specific problem using more than a hundred source code examples. Designers can work with previously acquired data from a file or generated by a simulation model as well. Sending the simulated signal data file to the hardware creates the real signal for testing.

## A Test Example

Consider the design of a wireless tire-pressure monitoring system. The U.S. government has required all new vehicles to have a malfunction

indicator lamp system by Sept. 1, 2007. Each tire contains a small pressure sensor attached to an ISM-band transceiver. A control unit in the dashboard transmits a command signal to the wheel transceivers, which in turn respond with a digitized version of the pressure to display to the driver.

The designer can easily build a simulation and test system for this project. Using the software, the binary command signal is passed through whatever coding is required, if any. Next, amplitude-shift-keying modulation is developed. The resulting signal is then upconverted to the 315-MHz ISM band. The digital file developed by the software is sent to a vector signal generator, which serves as the transmitter.

The wheel transceiver being tested receives the command signal and responds with a digitized pressure reading that is transmitted by frequency-shift keying in the 315-MHz ISM band. A vector signal analyzer acting as the receiver picks up the signal and downconverts it to an IF for digitization. The resulting data in Manchester or NRZ format is fed to the software that does the demodulation and decoding according to the standard or protocol. The signal then may be displayed and analyzed in a variety of ways to ensure compliance and correct operation.

While a relatively simple protocol and standard like that required for this application can be fully developed by the engineer, other wireless standards that are more complex are more than a challenge. In most cases, third-party developers create packaged software products to work with the software and modular hardware. ZigBee and the more popular cell-phone standards such as GSM and CDMA are examples of available standard software.

ED ONLINE 12357