COMMUNICATIONS-CENTRIC TEST GEAR SHARPENS SYMBOL RECOGNITION

BY MAURY WRIGHT • EDITORIAL DIRECTOR

DESIGNERS PURSUE NEXT-GENERATION WIRELESS DEVELOPMENTS WITH MODULATION-AWARE TEST TOOLS, THOUGH EVOLVING STANDARDS PRESENT PROBLEMS FROM THE PHY TO THE DATA LAYERS.

Designers working on wireless systems face a moving problem: In applications including 3G/4G cellular, WiMax, Wi-Fi, and UWB (ultrawideband), there is a constant progression to new, more complex standards. The development work—especially at the chip level—happens concurrently with standards development. Test-equipment companies are still finding ways to deliver products that allow development to proceed. The test tools increasingly include standards-specific capabilities at the PHY (physical) and higher layers of the network stack. A look at some sample tools and usage scenarios may help your next design project—whether you are working on one of these wireless standards, on a custom project in the ISM (industrial/scientific/medical) bands, or on a wired connection.

From the test-equipment manufacturers' perspective, the challenge centers on anticipating the market. Jennifer Stark, WiMax program manager at Agilent, points to three constant trends. "The technology is moving to higher frequencies, wider bands, and more complex modulation schemes," she says.

Clearly, the more complex modulation schemes offer the stiffer tests, as the most effective test gear includes the ability to handle the modulation schemes in real time. The incredible amount of digital-processing power readily available in baseband ICs makes the advances in modulation possible. But what you can accomplish in a baseband IC provides no comfort to the test-equipment company. With standards being moving targets, the test vendors use a combination of DSPs, FPGAs, and software to essentially model the transmitting and receiving ends of a communications link. Indeed, most of the test companies agree that they must virtually overdesign every instrument to allow a margin for use with emerging standards.

Justin Panzer, manager of product marketing at Rohde & Schwarz, states, "In a design environment, engineers use test equipment to try to simulate a real-world environment." But again, how do you simulate a technology in flux? Panzer points out that standards typically build upon one another. He uses the emerging LTE (long-term-emulation) standard as an example. The 3GPP (Third Generation Partnership Project) is developing LTE as a 3.5 or a 4G follow-on technology in the GSM (global-system-for-mobile)-communications family of cellular standards. "You see a lot of similarities to WiMax [in

LTE],” says Panzer. It appears that LTE will employ the OFDM (orthogonal-frequency-division-multiplexing) and OFDMA (OFDM-access)-modulation schemes that WiMax uses, but the frequency bands and channels differ. Most observers believe that LTE deployment is at least two years away, but chip designs are well under way (**Reference 1**).

MILITARY SCHEMES

“Most things that are tried in the commercial space have been tried in the military space,” says Agilent’s Stark. She claims that military LMDS (local-multipoint-distribution-service) and MMDS (multichannel-multipoint-distribution-service) systems were forerunners of the fixed flavor of WiMax. But, Stark adds, “Mobile WiMax is an enormous build on fixed WiMax.” Mobile WiMax requires that base stations hand off calls as the client moves. But a Mobile WiMax system can’t rely on channel assumptions that develop over time with a fixed client.

All of the test companies participate at some level in the standards bodies and therefore enjoy some visibility in shaping the direction of and even having influence over some decisions. “You can see two, three, or even four years out sometimes in the standards bodies,” says Graham Celine, senior director of marketing at Azimuth Systems. He also notes that disruptive standards can arise. For example, on a standard for the 700-MHz spectrum, the FCC (Federal Communications Commission) will hold an auction in the United States in February. TV broadcasters are about to vacate this spectrum. The highest bidder could for years potentially influence the course of US broadband history. “Until someone wins that auction, nobody knows,” says Celine.

As an example of how test companies influence standards, consider a WiMax case. Antonio Policek, senior marketing manager in Tektronix’s communications-business unit, claims that Tektronix influenced the inclusion of a metering port in base-station designs. The company implements the metering port at the output of the base-band stage and allows a protocol analyzer to gather data without having an RF receiver in the instrument. It seems that the test community largely seeks to ensure that standards are testable. “Azimuth wants to make sure that the test models make sense and can reasonably be implemented in instruments,” says Celine.

AT A GLANCE

- Wireless technologies push center frequency, bandwidth, and modulation complexity.
- Test companies scrutinize standards bodies but must anticipate the market.
- A signal generator, a signal analyzer, and modulation software can simulate a wireless network in the lab.
- Communication-test gear allows you to optimize the design of critical functions, such as the power amplifier.

MODELING WIRELESS SYSTEMS

It’s amazing how easy it is to model a wireless-communication system with modern test equipment in a development lab. National Instruments, for instance, offers a number of RF-signal-generator and -analyzer products in the PXI (peripheral-component-interconnect-extensions-for-instrumentation) and PXIe (PCI Express-extensions-for-instrumentation) form factors, which are essentially ruggedized versions of PCI and PCIe (PCI Express). You can use what’s essentially a PC with these hardware modules installed and completely model a cellular system using the company’s Modulation Toolkit software running on the LabView graphical-development environment. **Figure 1** depicts a symbol constellation and 3-D eye diagrams from a 16-QAM (quadrature-amplitude-modulation) system.

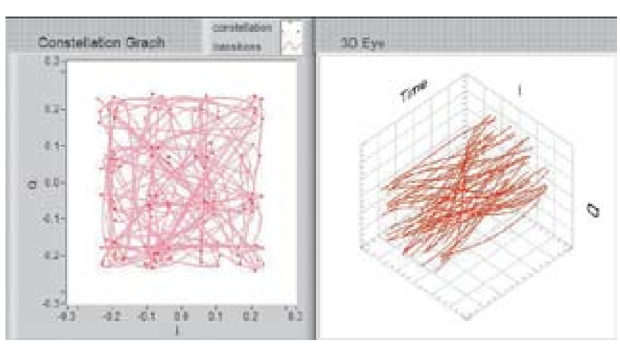

Figure 1 The Modulation Toolkit, which runs on National Instruments’ LabView, allows designers to quickly model wireless systems and offers diagnostic tools, such as this constellation and eye diagram.

A number of case studies illustrate the usage of the National Instruments tools. For instance, **Reference 2** describes a joint project between the University of Texas and Drexel University focusing on modeling MIMO (multiple-input/multiple-output) systems. The University of Texas also used LabView in 2003 to model early WiMax systems.

The modularity of National Instruments’ products also lends the tools to fieldwork. Recording RF energy in the field is one common task designers use to test products in the lab. It turns out that it’s tough to synthetically create the difficult environment that’s a reality in the field. David Hall, National Instruments product manager, points out that you can use one of the company’s VSAs (vector-signal analyzers) in a system with a hard drive to record five hours of a real-life environment that you can subsequently replay in the lab.

PUSHING FREQUENCY

To support testing and modeling of state-of-the-art wireless systems, the test companies must push their hardware design and add the software-based modulation tools. Going back to the three dimensions in which wireless technologies progress, Agilent’s Stark notes that individual standards tend to push in one or two of the dimensions but not in all three. She cites examples in WiMax and UWB. Stark claims that UWB, the most prevalent WiMedia flavor, uses a relatively simple modulation scheme but relatively wide 500-MHz channels. WiMax, conversely, uses relatively narrow 10-MHz channels but a complex modulation scheme. In both cases, the standards specify operation in the 5- to 6-GHz range.

Just the center frequency of a new standard can lead to the need for new hardware. Panzer of Rohde & Schwarz points out that the company’s CMU200 mobile-radio tester can work with virtually every cellular standard. But it operates only to 3 GHz, and, to support WiMax, the company had to develop the 6-

GHz CMW500 tester. And the hardware push doesn't stop there. To test a MIMO system, you would need two of the 6-GHz units.

Azimuth's Celine claims that MIMO was a difficult technology to support in test tools. Azimuth has focused on Wi-Fi and WiMax and bet on MIMO expertise early on as a way to differentiate the company. Celine points out that the channel emulator in a MIMO test instrument differs from the one in a traditional instrument. "In SISO [single input/single output], the emulator acts as an interference source," says Celine. "In MIMO, multipath is what makes the technology work."

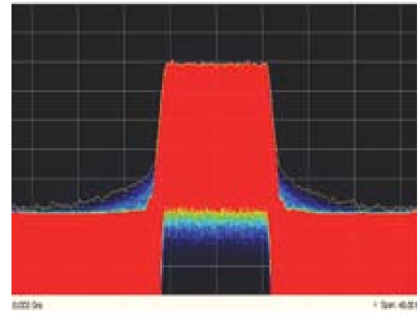

Figure 2 By continuously performing FFTs, Tektronix's real-time-spectrum-analyzer family can catch transients as short as 24 µsec, allowing the instruments to display overlapping-channel noise in OFDM systems.

AMP OPTIMIZES EXPERIENCE

Some usage scenarios help illustrate other instrument features and design challenges and detail just how you might use such an instrument in the lab. Agilent's Stark points at the power amplifier as a crucial part of an OFDMA radio design for a standard such as Mobile WiMax. She claims that a poor power-amp design can result in poor battery life, range, and data rate—attributes of a product that ultimately matter a lot to the consumer.

According to Stark, the power amplifier is an issue in the Mobile WiMax case, because the modulation scheme causes the design to drive the amp in a nonlinear range. Moreover, the output signal must change erratically and has a high peak-to-average ratio. The client side of a WiMax design also has space and heat constraints.

In this age of simulation and computer tools, you needn't build hardware to start a power-amp development. You can design and simulate the amp using Agilent's EEsof RF-modeling EDA tool. The EEsof tool can feed a signal generator, and you can use the 89600 VSA software on a PC to characterize your design. The VSA package runs on a PC and interfaces with a variety of Agilent oscilloscopes and signal-analyzer instruments.

Stark offers several examples of specifications that you can characterize and tune in this scenario. For example, a spec in WiMax and cellular standards that's commonly called either EVM (error-vector-magnitude) or RCE (relative-constellation-error) measures constellation accuracy. The power amplifier is one component that adds to EVM/RCE errors. A simple system that uses, say, BPSK (binary phase-shift keying) or 4-

With a frequency range to 3.3 GHz and optionally to 6 GHz, the Rohde & Schwarz CMW500 mobile-radio tester supports evolving standards, such as Mobile WiMax.

QAM (four-phase QAM), widely spaces the modulation symbols, and such a system can tolerate a high EVM/RCE figure. But a 64-QAM (64-phase QAM) system has a tight error budget, and, according to Stark, the amplifier's design often contributes a maximum of 1% of that error budget.

You can perform EVM/RCE tests only on a working radio. But the simulation component in Stark's scenario allows testing and optimizing before committing the design to hardware.

AMPS POSE PROBLEMS

Darren McCarthy, worldwide RF-technology-marketing manager in Tektronix's instrument-business unit, agrees that power-amplifier design is crucial to battery life and performance in wireless clients. McCarthy points out the need in an OFDM or OFDMA system to minimize power leakage from one channel into another. The test for such an occurrence is the ACPR (adjacent-channel-power ratio), a measurement of the linearity in a system.

As noted, however, systems such as Mobile WiMax and LTE drive power amplifiers into nonlinear regions—negatively impacting the ACPR. Increasingly, designers are turning to techniques such as DPD (digital predistortion) to minimize ACPR. But DPD introduces a new problem: memory effects, which result from electrical traits, such as source and load impedance and electrothermal coupling.

Traditionally, designers use spectrum analyzers and software tools to measure ACPR. But McCarthy claims that such ACPR measurements measure average power and that traditional spectrum analyzers using a swept-spectrum approach miss transient signals, such as those that memory effects cause. Tektronix offers a family of real-time spectrum analyzers that continuously perform frequency-domain transformation to catch memory-effect transients. **Figure 2** shows a Tektronix digital-phosphor-spectrum display.

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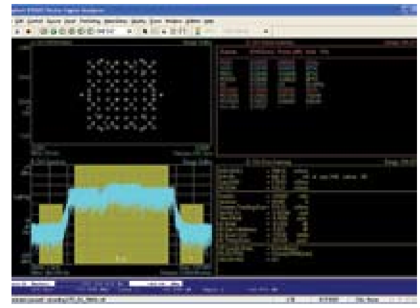

The 89601A LTE signal-analysis package from Agilent performs an EVM (error-vector-magnitude) measurement on an LTE downlink signal, and the package displays a constellation diagram.

The yellow curve indicates the maximum occurrence of noise in the adjacent channels. McCarthy claims that the instrument will capture any transient that lasts 24 μsec or longer.

Equally important, according to McCarthy, is the ability to tie the occurrence of a problem transient with the root cause. The instruments support frequency-masked triggering, and you can connect that trigger to a variety of other instruments. McCarthy claims that you can use such a trigger to locate the software instruction that caused a gain change in the amplifier and, therefore, the transient.

UWB AND OTHER STANDARDS

Wide-area wireless technologies aren't the only technologies that are changing. And designers certainly need good test gear for standards such as UWB. Tektronix's McCarthy claims that standards such as UWB and IEEE 802.11n offer special challenges because they offer "cognition of the environment." Such cognitive radios are especially important in standards that use the unlicensed spectrum, because the radios must avoid interfering with other transmitters.

The UWB community has developed the DAA (detect-and-avoid) technique to ensure that the broad transmissions don't interfere. Europe, Japan, and some other regions will mandate DAA. McCarthy points out that, although UWB's transmitting power is far lower than that of, say, a cellular transmitter, a UWB transmitter could still interfere with a cellular receiver. So, DAA basically specifies listening for a transmitter and avoiding frequencies in which a transmitter is operating.

Several operational modes exist for DAA implementations. UWB features three 500-MHz channels among which UWB radios hop. In the simplest form, DAA does not use one of the three channels when another transmitter is present. In many cases, however, a system can take a more granular approach to avoiding interference. Using a tone-nulling technique, a transmitter simply avoids a narrow range of subcarriers within one of the 500-MHz bands. According to McCarthy, the Tektronix AWG7000 signal generator with optional UWB software allows design teams to test all DAA modes.

THE RUSH TO LTE

Looking forward, all of the test vendors are working feverishly on LTE products in the lab and shipping some products, as well. Panzer from Rohde & Schwarz claims that the company early on engaged with a leading chip vendor and has delivered gear that can handle PHY and RF tests. Indeed, the CMW500, which also supports WiMax, offers LTE support.

Azimuth's Celine maintains that the challenge everyone will face is effective MIMO support. He believes that the MIMO experience the company has gained with WiMax will serve it well in an upcoming LTE product. "LTE is in a very different frequency band," he says. "We are redesigning the RF front end, but that's easier than handling a new modulation scheme."

Regardless of what type of system you are working on, you might consider one common thought that all of the test vendors have voiced: Standards for technologies such as wireless communications don't provide design advice. "A standard document defines system performance," says Agilent's Stark. "It doesn't tell the engineer how to design." You probably knew that fact. But it means that you had better thoroughly test your design and that wireless channels probably offer more unknowns than any other environment in which you will ever work. EDN

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