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4G TELECOMMUNICATION TECHNOLOGY CARRIES EXPLICIT REQUIREMENTS FOR MINIMUM NETWORK SPEED. DESIGNERS MUST FIND A WAY TO RELIABLY AND COST-EFFECTIVELY REACH THOSE TARGETS.

GETTING TO 4G THROUGH DESIGN AND TEST

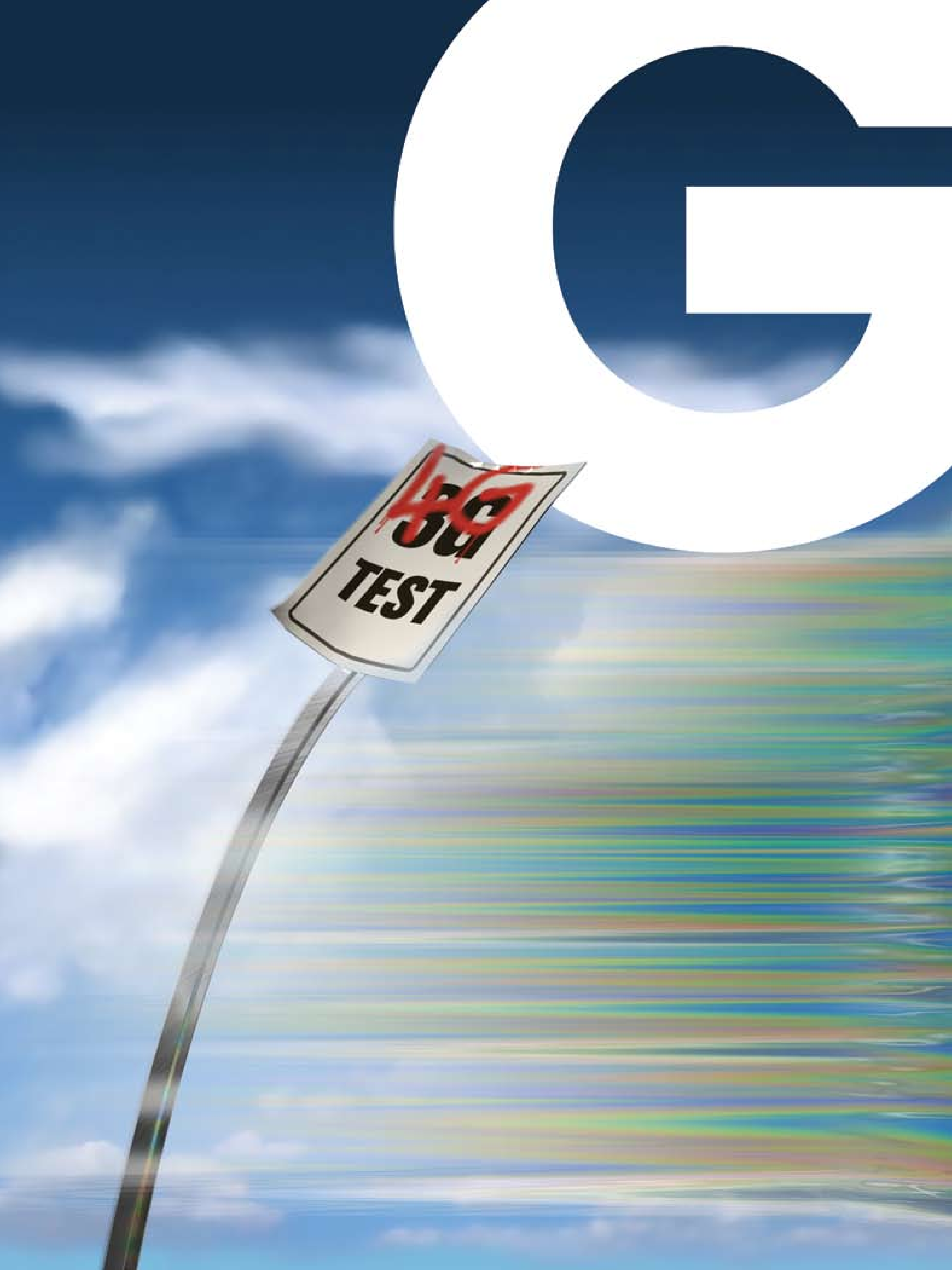
As TODAY'S telecommunication technology proceeds forward to 4G (fourth generation), it requires a minimum network speed of 100 Mbps in high-mobility situations and 1 Gbps in low-mobility scenarios. The goal might seem more manageable if 4G represented an ultimate goal—that is, a finish line. Instead, it is only the latest point in a continuum that stretches beyond the foreseeable future (**Figure 1**). Whatever level of performance engineers can deliver, customers will find reasons to demand more. In short, data expands to fit the available bandwidth. In other words, if you build it, the data will come, and the infrastructure to support that performance must also evolve.

In addition, 4G designers using 3G (third-generation) technology as a base find themselves shooting at a fixed target from a moving train. Enhancements to 3G, including 3.5, 3.75, and 3.9G, do not erase the line that separates them from the Holy Grail of 4G but may reduce the appeal of the generational transition. Adding to the mix are the two primary flavors of 4G, based on LTE (long-term evolution) and WiMax (worldwide interoperability for microwave access).

BUMPING AGAINST THE STANDARDS

The ITU (International Telecommunications Union) describes 4G's proposed key features, most of which leave much room for maneuvering. The ITU calls for worldwide commonality and compatibility, interoperability with other radio-access systems, user-friendly applications, and the like, describing a range of actions rather than a standard for compliance. Only the target speed truly represents a sharp departure from its predecessor. Hence, designers are tempted to implement some of the anticipated 4G features and declare intermediate generations that remain short of true 4G.

Even the target speed to qualify as 4G isn't set in stone. The 1-Gbps speed is not only limited to low-mobility or stationary applications, but also requires ideal radio conditions and, more significant, as much as 100 MHz of bandwidth. The frequency spectrum is sufficiently crowded that myriad 100-MHz-wide bandwidth


TEST

AT A GLANCE

- The 1-Gbps speed of 4G (fourth-generation) technology is not only limited to low-mobility or stationary applications, but also requires ideal radio conditions and as much as 100 MHz of bandwidth.
- The two leading candidates for 4G–LTE (long-term evolution)-Advanced and WiMax (worldwide interoperability for microwave access)–have somewhat different pedigrees.
- The realities of the infrastructure and the economics of managing a major transition mean that 4G adoption will prove slower than its proponents might like.
- The transition to 4G will require multiband transmission and reception, increasing power consumption.

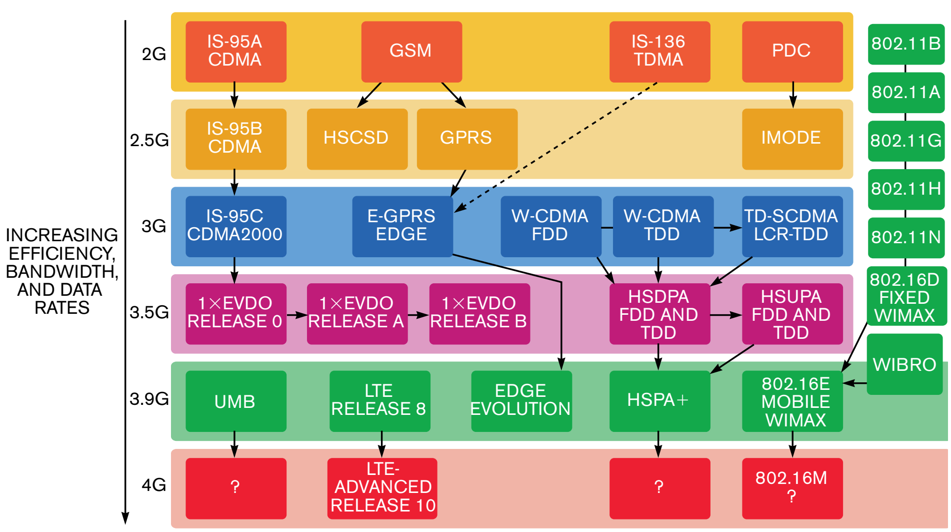
bundles may prove difficult to find. Not everyone even agrees on what 4G is. Whether a configuration qualifies may depend on the agenda of the person you are asking. Mark Buffo, director of business development for Keithley Instruments, considers the current use of the term to represent more marketing than technical specification. "Some existing technologies will coalesce into 4G," he says. "They may not start out with all of the theoretical functionality, evolving over time. Right now, what a lot of people are describing as 4G does not actually represent a uniform and consistent level of performance."

The two leading candidates for 4G have somewhat different pedigrees. The developers of so-called LTE-Advanced based the technology on UMTS (universal mobile-telecommunications system), which the 3GPP (Third Generation Partnership Project) defines. "Officially, LTE is still a 3G standard, despite the fact that people refer to it as 3.9G and that it has nothing in common with UMTS," says Moray Rumney, lead technologist with Agilent Technologies. LTE-Advanced's developers in December 2008 froze the standard for base stations, network infrastructure, and other centralized functions and plan a proposed standard for Release 10 of the 3GPP specifications in September 2009. The group intends LTE-Advanced to be compatible with LTE and other earlier technologies to ease the transition. One goal of the transition will be to simplify the system architecture and the maintenance requirements to reduce costs, according to Phil Medd, product manager for UMTS test systems at Aeroflex's Test Solutions, Wireless Division. The backward compatibility will facilitate that effort. "LTE initially will be a data-only service," he says. "Users will continue to access conventional GSM [global-system-for-mobile communication] for transmitting voice."

WiMax evolved from the IEEE 802.11 WLAN (wireless-local-area-network) standard. The 4G Mobile WiMax will come in the form of IEEE 802.16m, which in turn came from 802.16e. The differences between the two 4G technologies reflect their origins. "WiMax is trying to establish a broad standard," says Keithley's Buffo. "LTE is more focused. LTE comes from the telecommunications world, whereas WiMax comes from data communications." Many of the larger service providers, such as Verizon, have committed to adopting the LTE version of 4G. Some of the smaller players, including Sprint, have opted for Mobile WiMax.

Design engineers may have a hard time navigating this uncertain environment. They should remember, however, that their world is far removed from the pronouncements of the standards bodies, according to David Hall, a product manager at National Instruments. The standards establish higher data rates as their ultimate goal. He suggests that cellular systems are so complex that few engineers will base their designs on that criterion alone, preferring to rely on such metrics as better power-amplifier efficiency, EVM (error-vector magnitude), adjacent-channel power, quadrature skew, noise figure, and sensitivity. "In the end, the winning 4G technology will be determined more by a handshake than a field test," says Hall.

Lynne Patterson, a business-development manager for wireless-infrastructure test-and-measurement products at Anritsu, contends that the relative success of LTE-Advanced and Mobile WiMax will differ from country to country. "Currently, North America doesn't need the broadband access that Mobile WiMax is offering," she says. "Here,



1×EVDO: ONE-TIMES EVOLUTION DATA OPTIMIZED
CDMA: CODE-DIVISION MULTIPLE ACCESS
EDGE: ENHANCED-DATA-GSM ENVIRONMENT
E-GPRS: ENHANCED GENERAL PACKET-RADIO SERVICE
FDD: FREQUENCY-DIVISION DUPLEX
GPRS: GENERAL PACKET-RADIO SERVICE
GSM: GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS
HSCSD: HIGH-SPEED CIRCUIT-SWITCHED DATA
HSDPA: HIGH-SPEED DOWNLINK-PACKET ACCESS
HSPA: HIGH-SPEED PACKET ACCESS
HSUPA: HIGH-SPEED UPLINK-PACKET ACCESS
IS: INTERIM STANDARD
LCR-TDD: LEAST-COST ROUTING/TIME-DIVISION DUPLEX
LTE: LONG-TERM EVOLUTION
PDC: PERSONAL DIGITAL CELLULAR
TDD: TIME-DIVISION DUPLEX
TDMA: TIME-DIVISION MULTIPLE ACCESS
TD-SCDMA: TIME-DIVISION SYNCHRONOUS-CODE-DIVISION MULTIPLE ACCESS
UMB: ULTRAMOBILE BROADBAND
WCDMA: WIDEBAND-CODE-DIVISION MULTIPLE ACCESS
WIBRO: WIRELESS BROADBAND
WIMAX: WORLDWIDE INTEROPERABILITY FOR MICROWAVE ACCESS

Figure 1 Wireless-telecommunications technology will have advanced dramatically by 2010 (courtesy Agilent).

we can already access broadband communications easily. In parts of the world that don't have immediate access to either fixed or mobile broadband, however, Mobile WiMax offers significant advantages."

Implementing the next big step may be tempting. The realities of the infrastructure and the economics of managing a major transition, however, mean that 4G adoption will prove slower than its proponents might like. In 112 countries, 252 operators have adopted HSPA (high-speed packet access), the 3G technology that currently provides the highest available mobile bandwidth. Even if 4G represents the revolutionary advance that its supporters claim, it must overcome a great deal of inertia to displace that sizable installed base. Verizon, for example, has committed to deploy some small LTE-Advanced systems later in 2009 and to launch commercial service in 2010.

In addition, achieving simplicity of architecture may prove elusive. "For the foreseeable future, handset manufacturers will have to provide triband and quadband phones that can handle, say, European and US versions of GSM," says Keithley's Buffo. "Users will demand seamless transitions. The devices themselves will have to figure out which band they need to address in real time."

SIZE MATTERS

Designing for this new world and verifying that the design works will depend heavily on the makeup of the telecommunications network itself. Whether a piece of equipment addresses the 700-MHz band, which analog-television stations are currently abandoning, or the 3.2-GHz band will determine the size of the antenna it requires and the effect of intervening objects, such as buildings or geographical objects in the signal's path, on its range. Lower-frequency signals can travel farther than their higher-frequency counterparts with the same amount of power. Unfortunately, no good deed ever goes unpunished. Antenna size depends on the signal's wavelength. Lower frequencies have longer waves and, therefore, need larger antennas. Building an adequate low-frequency antenna into a cell phone may prove impractical, although designers may be able to fit such an antenna into the lid of a laptop computer.

Figure 2 Test equipment such as the Rohde & Schwarz radio-communication tester plays a prominent role in 4G technology.

Power consumption depends on more than frequency. The transition to 4G will require multiband transmission and reception. Multiband performance also increases power consumption, reducing battery life in cell phones and laptop computers. Maintaining throughput and network capacity to accommodate the higher data speeds and volumes will rely on MIMO (multiple-input/multiple-output) antennas, another power drain. Tony Opferman, engineering program manager for Rohde & Schwarz, speculates that, at least initially, cell phones will not include MIMO antennas. Mobile-broadband data cards for laptops and other computers and televisions with broadband capabilities will be more likely candidates.

And what about cost? Development and deployment of the 4G technology will likely prove tremendously expensive. How much will customers be willing to pay for 4G? Will it turn out to be a luxury with only a niche market? How will designers balance the demand for features with the call to lower costs? Keithley's Buffo speculates that end customers will continue to demand the smartest phones with the highest data rates, transferring more data faster with less latency, and be willing to pay premium prices for the privilege. Mobile Internet users will demand the same experience that they can get with a wired device. "Industry prognosticators have asked [why people will need that level of performance] in response to every revolutionary technological change," he says. "Using Amazon's Kindle as an example, innovative products stimulate their own demand." Buffo recognizes that the current state of the economy will slow the implementation but insists that, five years from now, we will wonder how we could ever have doubted that it would happen.

At the same time, demand for high-end performance will vary widely between the developing and the developed world. In emerging markets, in which people have less disposable income, the price-versus-performance trade-off will have to skew toward keeping costs down. The economic downturn has made even customers in developed countries more careful about spending their money. To meet their needs, designers will want to find ways to provide equivalent features for the same or lower prices.

The other end of the network presents formidable challenges, as well. Massive increases in data traffic will place enormous demands on the communications infrastructure. The Apple iPhone's introduction caused massive network traffic jams, dropped calls, and other problems. In migrating to 4G, operators must remain cognizant of its overall effect.

Designers for this next generation may have to rethink the structure of the network itself. Until now, mobile operators

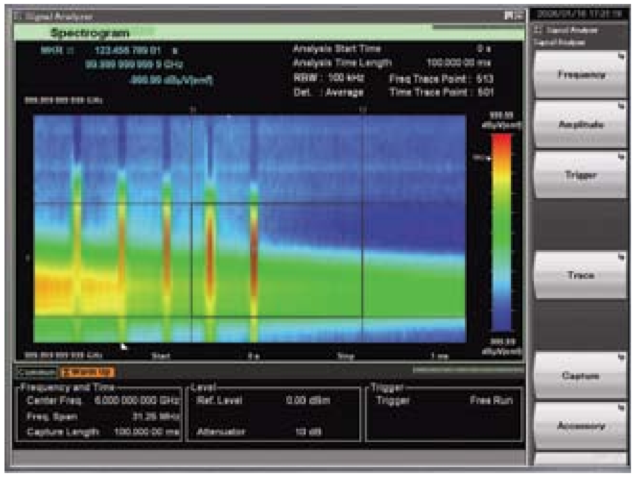


Figure 3 A signal analyzer's spectrogram function shows a 3-D representation of an LTE signal. Vertical cursors allow users to select a particular slice of data in the time domain, and horizontal cursors allow users to designate a frequency of interest (courtesy Anritsu).

have tried to increase system capacity by increasing peak and average data rates, an expensive and eventually inadequate approach. Increasing capacity by reducing cell size can also prove an expensive alternative. Agilent's Rumney suggests the need for a paradigm shift employing femtocells. Each cell might cover only a couple of buildings. The user would purchase the base station, a highly integrated commodity product costing perhaps $100 and offering a range as long as 10m. Although not a low-cost approach, it dramatically changes the dynamic of how users and providers spend their money.

The companies making base stations today, accustomed to "big" design, might resist such a shift. The emergence of numerous new players that lack the historically high overheads of the traditional players has forced their hand, however. After some hesitation, operators and traditional base-station manufacturers have begun to embrace the femtocell approach.

TESTING THE UNKNOWN

In the middle of all this turmoil, how do you test the base stations and end-user equipment for this new technology? The standards are constantly changing. Each standards body will establish its own test criteria. Buffo contends that LTE's requirements are clear. With WiMax, the features are still evolving, so it is harder to determine what the final version will look like.

The new technologies have created the need for a new type of test tool that is flexible enough to adapt to whatever is the latest version, according to George Reed, vice president of marketing and product management for Azimuth Systems. Designers have no choice but to rely on the current status of the standards, designing against them and making necessary modifications as the standards evolve. Still, the overall goal of test hasn't changed. Engineers must functionally verify the end products. Expecting a test-equipment manufacturer to constantly introduce new hardware would be impractical. Nevertheless, the communications products and the testers are radio systems, and all radio systems have traits in common (**Figure 2**). An RF instrument can acquire many types of signals and apply a measurement algorithm specific to the standard under test. A manufacturer can modify a versatile system that incorporates high-performance DSPs, upconverters, ADCs, and so on, along with a software-defined radio, in response to changes in the standards or the technology.

Testing MIMO antennas also introduces complications to a traditional test approach. National Instruments' Hall notes that vendors are introducing more flexible instrumentation hardware targeting the MIMO test challenge. New RF generators and analyzers allow synchronizing sample clocks and local oscillators, so that designers can address some of the more difficult MIMO measurements.

Another consideration is that designers of base stations that address the new standards often lack matching handsets to verify that they work. Conversely, handset manufacturers generally lack access to real base stations. Instead, they rely on emulators that mimic the behavior of the other end of the network. Emulation offers additional flexibility. Also, the introduction of 4G will not mean that all 3G technologies will suddenly vanish. New designs will have to work seamlessly with the existing infrastructure until sometime in the distant future when everything aligns with 4G standards. By that time, the state of the art will likely be 5G (fifth generation) or 6G (sixth generation), and the cycle will begin again. A base-station or cell-phone emulator can verify that any design remains compatible with earlier versions of the communications network (**Figure 3**).

Paul Goodling, product-line manager for Rohde & Schwarz, states that the developers of both LTE-Advanced and Mobile WiMax based them on the same physical layout. LTE has the more defined specification because of its history with 3GPP, which had established issues such as handover and signal security. Goodling believes that LTE will dominate in wireless communications, and that WiMax will more likely flourish in stationary applications, such as in-home telephone systems or laptops. "But when it comes to testing," he remarks, "you can consider them different flavors of the same platform. A single-box solution can address all of the current standards. That reality allows for a smoother transition."

The transition to 4G communications will proceed in fits and starts. Adoption will at first be spotty and will expand over time. It is the same pattern that occurred with the transition from 2 to 3G, and it will repeat again with the next generation. Designers must keep their creations nimble, able to respond to ongoing changes to the standards as they evolve. One thing is certain, however: The demand for communications performance will not stop with 4G, or with any other generation. A few years ago, an industry prognosticator predicted that the communications revolution of the next 10 years would make the computer revolution of the previous 10 years pale by comparison. Some would call that an understatement. EDN

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