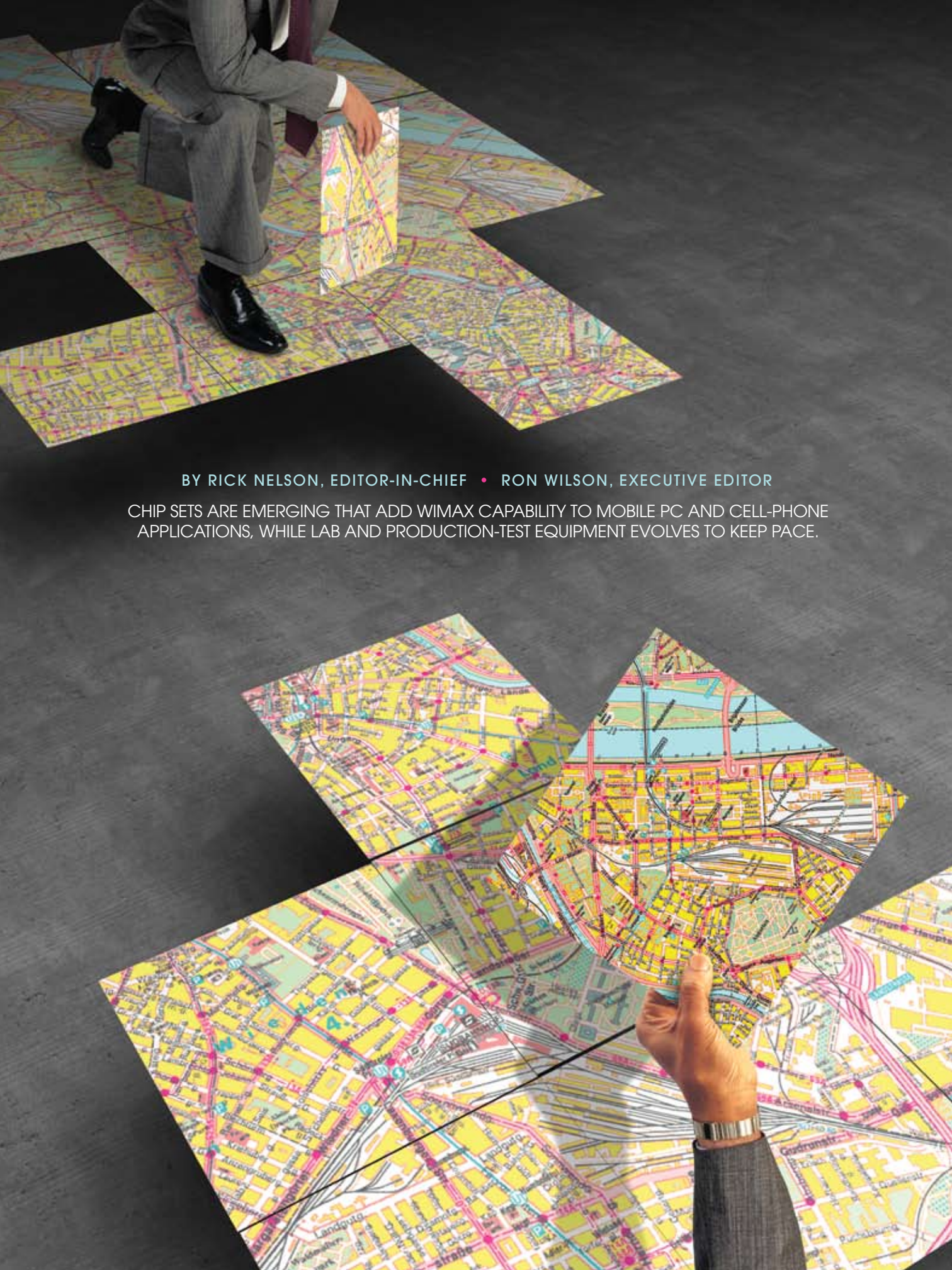

BY RICK NELSON, EDITOR-IN-CHIEF • RON WILSON, EXECUTIVE EDITOR

CHIP SETS ARE EMERGING THAT ADD WIMAX CAPABILITY TO MOBILE PC AND CELL-PHONE APPLICATIONS, WHILE LAB AND PRODUCTION-TEST EQUIPMENT EVOLVES TO KEEP PACE.

LAYING SEAMLESS WiMAX FABRIC

WiMax (worldwide interoperability for microwave access) stands poised to extend coverage in PC networking and mobile-phone communications as semiconductor makers roll out WiMax chip sets and as test-equipment vendors offer the lab instrumentation and production ATE (automatic-test-equipment) systems necessary to test the chip sets and the products they populate. WiMax shows promise as a technology for PC networking as well as a potential cellular technology (see **sidebar "**WiMax markets and opportunities"). Paul Argent of Aeroflex expects WiMax to initially bring broadband-wireless access to laptops despite suggestions from WiMax Forum members that WiMax is a technology for multiple applications, including cellular telephony. Over the next two years, Argent says, WiMax will primarily provide high-speed data access to PCs in coffee shops as well as in moving vehicles.

Jennifer Stark, Agilent's WiMax business-team leader, cautions that you should not consider WiMax as a replacement for other broadband-wireless-access technologies. She segments wireless technologies by range—with personal-area networks, such as UWB (ultrawideband) and Bluetooth, operating at 10m or less; WLANs (wireless local-area networks) operating at 100m or less; and WiMax operating at three to 10 miles or more. As for WiMax's competing with WLANs, she expects them rather to complement each other, with appliances making the most effective connection based on conditions of the moment. For instance, WiMax will be the choice if you're on a train going 50 mph, she says; if you later find yourself in a stationary situation, WLAN might be the best choice.

WIMAX-CHIP TEST

To test WiMax chips in production volumes, ATE makers are adapting their RF-capable systems to handle WiMax-test requirements, and makers of bench- and rack-mount test equipment are tailoring their instrumentation to handle a potential onslaught of components, modules, and WiMax-compatible appliances. These vendors are also addressing the test needs of service providers that will install and maintain the WiMax infrastructure. Adam Smith, a business-development engineer at Verigy, says that WiMax test represents an evolutionary step from WLAN test, with WiMax imposing stricter requirements as designers try to cram ever more features into a tighter space. "From a test-equipment point of view," he says, "your equipment needs to have very good noise performance; it needs to be very sensitive." Agilent's Stark adds that WiMax's underlying OFDM (orthogonal-frequency-division-

multiplexing) scheme results in high peak-to-average power levels, putting a premium on highly accurate power-amplifier measurements.

Testing of WiMax silicon presents an instructive bundle of issues to chip designers and test engineers. On one hand, if WiMax is to reach wide acceptance, test costs—including the cost of silicon overhead to support testing—must be as small as possible. Ultimately, says Smith, someone will want to fit WiMax capability within a $99 mobile device. On the other hand, a number of factors militate against a fast, comprehensive test procedure. The WiMax standard is still not mature. Adjustments are by now small, but they still happen. More important, the standards reach only far enough to attempt to ensure interoperability at the system level. They make no demands on the implementation approach or on the signals passing between functional blocks in the implementation. Even more troubling, you may find that you don't have access to signals between functional blocks. Ken Harvey, senior product technologist at Teradyne, points out that, as WiMax chips become increasingly integrated, you'll find you might not have direct access to I (in-phase) and Q (quadrature) signals. "You'll go straight from RF to bits," he says.

Lacking standards against which to test the signal between the RF mixer and the ADC, and—potentially—access to that signal, you'll have to rely on system-level requirements, such as the EVM (error-vector magnitude) of the resolved signal and bit-error rate of the data stream. Agilent's Stark elaborates on this point. She divides the WiMax market into four segments: chips and components; modules, for which chip makers' reference designs sometimes substitute; appliances; and service providers. She concurs that EVM is a system-level spec that requires measurement at the appliance level but cautions that designers must be aware of component and module EVM of a power amplifier, for example, so that they can stay within an overall EVM budget. Ultimately, she says, test will play a key role as vendors try to differentiate their components in features, RF performance, and power consumption as they strive to fit WiMax capability within the tight constraints of appliances. Stark points out that WiMax-appliance vendors fortunately won't create brand-new devices that you've never seen before. The use case for WiMax, she says, is to add WiMax to currently available devices, such as laptops, PDAs (personal digital assistants), and cell phones.

But just how a system, no matter how familiar, reaches adequate system-level performance standards varies depending on the baseband software, system design, and intended operating environment of that system. So, there is no straightforward translation between WiMax's system-performance specifications and testable behaviors on WiMax silicon.

The testing problem is easier in some functional blocks than others, however. The digital baseband, for instance, from a testing point of view, is just another fast signal processor. According to an Intel engineering spokesman, "WiMax silicon is not very different from any other SOC [system-on-chip] testing we perform at Intel. The part goes through Intel's strict product-reliability and qualification guidelines that include wafer testing, ESD [electrostatic-discharge] stressing, burn-in, and analog/mixed-signal testing across a broad range of temperature, environmental, and power-supply variability conditions. WiMax silicon can use the same DFT (design-for-test) techniques and hardware structures that are common in SOC design, such as at-speed scan, ATPG [automatic test-pattern generation], and logic and memory BIST [built-in self-test]. The process also includes package qualification, and silicon performance testing on multiple skew lots, as well as normal silicon lots."

Baseband silicon is a specialized, but still programmable, signal processor. It is either working correctly, or it isn't. Designers must adjust the software to the application, and that challenge is not a testing problem.

AT A GLANCE

- WLANs (wireless local-area networks) and WiMax (worldwide interoperability for microwave access) should complement, rather than compete with, each other.
- ATE (automatic-test-equipment) makers are adapting their RF-capable systems to handle WiMax-test requirements, and makers of bench- and rack-mount test equipment are tailoring their instruments for an onslaught of components, modules, and WiMax-compatible appliances.
- WiMax standards reach only far enough to attempt to ensure interoperability at the system level.
- Designers must be aware of component and module EVM (error-vector magnitude) so that they can stay within an overall EVM budget.
- High-performance ATE lets you characterize silicon on the ATE itself, smoothing the transition to high-volume production test.

The Agilent E6651A WiMax test set supports protocol-conformance test as well as base-station emulation and RF-parametric measurements.

ANALOG SPACE

If you talk to a vendor of RF silicon, you get a different view. In the digital world, chip variations don't alter the

performance of a device until they become so severe as to break the circuit. In the RF and analog domains, variations in the chip are variations in the chip's performance. As one old chestnut has it, you test digital circuits, but you characterize analog ones. This distinction changes the approach test engineers must take to an emerging technology such as WiMax.

"WiMax is all over the place right now," says Tom Gratzek, business director for the WiMax silicon program at Analog Devices. "There are different frequency bands, different bandwidth requirements, different baseband filtering schemes; everyone has an approach." The company offers WiMax front-end silicon, which includes the RF stages, mixers, ADCs, DACs, and some digital filtering. Gratzek says that Analog Devices tests the digital portions of the chips in the same way as it does any other digital circuitry: with scan-based BIST. After that, things get more complex, however.

"We have to examine the analog signal chain for defects," Gratzek says. "That by itself requires hundreds of milliseconds of test time. After that, the only approach we have found to predict how the chip will work in the customer's system is to stimulate the silicon at speed." This testing is not, Gratzek explains, a full characterization. Rather, the test program is an artful compromise that the company bases on the full characterization of skew lots in the engineering lab, on the ability of test engineers to elegantly check many degrees of freedom with a few tests, and on continuous feedback from the company's applications engineers who work on customers' designs. Analog Devices drives the receiver with 2-, 3-, and 4.9- to 5.9-GHz-band test signals and drives the transmitter with corresponding digital vectors. "We sweep three frequencies in each band," Gratzek says. "Unfortunately, that [approach] forces us onto mainframe RF testers, and it adds seconds of test time."

This approach is not unique. Infineon engineers report that they also generally stimulate their WiMax silicon at speed. They use a standard 64-QAM (64-state-quadrature-amplitude modulation) Rate 2/3 of a 3.5-MHz-bandwidth signal at 4 MHz as a starting point. But Infineon is seeing increasing pressure for customers with video-over-broadband applications to expand the bandwidth to 10 or even 20 MHz, causing changes from the silicon on up through the testing program.

Even moving to mainframe RF ATE isn't the whole solution, though. Gratzek says that Analog Devices has augmented its testers' already-formidable hardware with some custom spectral-analysis gear. That equipment also integrates some proprietary design features in the silicon and the device-under-test card to increase coverage and reduce test time. This allows the test team to sweep frequencies for an end-to-end test on the receiver side, for instance, driving the antenna inputs to the LNA (low-noise amplifier) and analyzing the output stream from the ADC for EVM and noise figures.

These top-line numbers give the company a go/no-go indication and more on each die. For instance, the engineers can infer the SNR (signal-to-noise ratio) and linearity of the ADC from the end-to-end test. But the test team can extract even more detailed information as well, due to the high degree of digital configurability of the RF design. "We can manually control the automatic-gain-control loop, and we do so during test," Gratzek says. "We can also disembed the digital filters on the output of the chain to examine the raw digital data. And we can force the analog filters to specific characteristics, step through the gain settings on the LNA, and so forth." This approach allows the test team to move, if necessary, from the end-to-end test to an almost diagnostic level of examination while still on the production-test head.

This flexibility comes in handy. "We are delivering WiMax chips to all sorts of customers' evaluation boards, and

WIMAX MARKETS AND OPPORTUNITIES

Embedded mobile WiMax in mobile PCs will drive the emerging WiMax chip set market through 2012, says In-Stat (Reference A). "The market-research company predicts that Intel's combination Mobile WiMax (interoperability for microwave access) and Wi-Fi Echo Peak module, which will launch as an option to the company's Montevina mobile processor platform in 2008, will drive the adoption of embedded WiMax into mobile PCs. WiMax CPE (customer-premises equipment), external clients, and dual-mode cellular/WiMax handsets will also help drive WiMax-chip-set volumes through 2012, the company reports.

"The total WiMax user terminal-chip-set market will reach almost $500 million in 2012, growing from $27 million in 2007," says Gemma Tedesco, In-Stat analyst, in a press release. "Furthermore, WiMax base-station-semiconductor revenues are expected to be approximately $1.4 billion in 2012, compared to $130 million in 2007."

In a separate report, In-Stat says that, from a mobile operator's perspective, mobile WiMax provides more of a service complement than a competitive threat (Reference B). The company notes that the mobile standard for WiMax has been the subject of debate since its inception, with debaters falling into two camps.

"One camp led by select equipment vendors with no stake in WiMax has taken an either/or approach to discussing mobile WiMax," says Daryl Schoolar, In-Stat analyst, in a press release. "Any gain by WiMax comes at the expense of other 3G data technologies. In the other camp, infrastructure vendors, such as Alcatel-Lucent, Motorola, and Nokia Siemens, see a world where multiple mobile wireless-broadband technologies will coexist. In-Stat believes that this camp's view will prevail."

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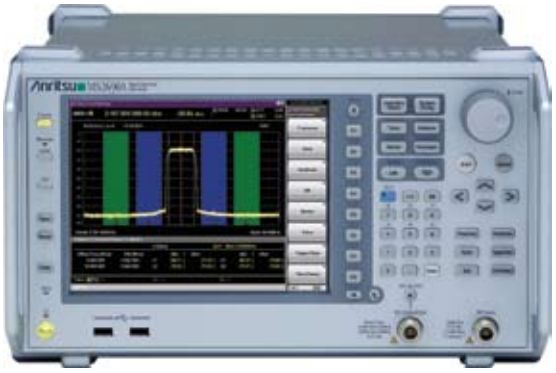
The CMU270 single-instrument production tester from Rohde & Schwarz makes signaling and nonsignaling measurements of WiMax mobile stations and customer-premises equipment.



Anritsu M2690A/M2691A signal analyzers operate from 50 Hz to 6 GHz and can measure the transmitting power of mobile-WiMax devices.

they use the silicon in many ways," Gratzek says. "Our applications engineers feed use data back to the test team, and we try to adjust the tests to anticipate the sensitivities of a … customer application. For instance, many customers change the filter settings to get the EVM they want on a … board and antenna configuration. We try to adapt to that [configuration]." This approach means that the application-support team reserves time on the test floor for development purposes.

Commercial-test companies are working to streamline WiMax test. ATE vendors including Advantest, Teradyne, and Verigy are tailoring their systems to test WiMax devices in multisite configurations. Verigy's Smith says nothing is magical about WiMax. UWB is dealing with new spectra, but WiMax aims to make more efficient use of the allocated spectrum, he says. WiMax test is well within the capabilities of his company's Port Scale RF instrument, which Verigy introduced last summer for the V93000 system. Similarly, Advantest's 12GWSGA RF module, which the company introduced last fall for its T2000 test system, and Teradyne's UltraWave, which the company introduced in March, will handle WiMax-chip test.

Semiconductor-ATE systems have typically focused on high throughput without necessarily providing the performance of bench-top and rack-mount instrumentation, but the advent of WiMax is changing that scenario, says Teradyne's Harvey. Measurement requirements are becoming so stringent, he says, that ATE instruments must approach bench and rack versions in measurement capability. He cites an additional advantage of high-performance ATE: It lets you characterize silicon on the ATE itself, smoothing the transition to high-volume production test.

Companies that provide test equipment for WiMax modules and appliances as well as components include Anritsu, Agilent Technologies, Aeroflex, Tektronix, and Rohde & Schwarz, all of which make general-purpose test and measurement equipment that can perform tests on WiMax systems as well as dedicated WiMax boxes and software.

Tektronix, for example, offers the K1297-G35 WiMax protocol analyzer, which provides protocol simulation, emulation, and monitoring. In addition, Tektronix offers for its real-time spectrum analyzers the RSA-IQWiMax software, which can help detect, diagnose, and resolve WiMax-design errors. Rohde & Schwarz offers the CMU270 single-instrument production tester as well as the TS8970 WiMax-radio-conformance-test system. Anritsu offers bench-top signal-generation and analysis instruments, such as the MS2690A signal analyzer and MG3700A vector-signal generator, as well as the handheld MS2724B spectrum analyzer, which can make fixed- and mobile-WiMax measurements in the field.

Aeroflex offers WiMax-test equipment in PXI (PCI-extensions-for-instrumentation) and traditional rack-and-stack formats for testing WiMax base stations and mobile devices "from birth to death," says Argent of Aeroflex. He notes that, before vendors submit their WiMax devices to WiMax Forum-certification labs, they would benefit from doing their own precertification tests to help ensure that their devices pass the first time. When WiMax Forum labs are charging approximately $500 per hour, he says, customers will want to have maximum confidence that their products will pass quickly.

Agilent's offerings extend from the EEsof division's ADS (Advanced Design System) design and simulation software to WiMax-drive-test systems. Along the way, the company offers a complement of signal-generation and -analysis equipment, which can link to ADS through Agilent's Connected Solutions technology, as well as WiMax protocol analyzers and logic analyzers for baseband development and troubleshooting.

Test cost will be paramount—for chips, modules, appliances, and infrastructure installation and maintenance. Gratzek of Analog Devices summarizes the cost issue from a chip maker's perspective: "On our GSM [global-system-for-mobile-communication]-product line, we were able to substantially reduce the test cost as the market matured," he says. "We aren't at that stage yet with WiMax, but we have planned for it. We designed our ATE strategy from the beginning with an end cost point in mind and a path to get there. We may well reduce the test cost by a factor of three as the technology matures." EDN

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