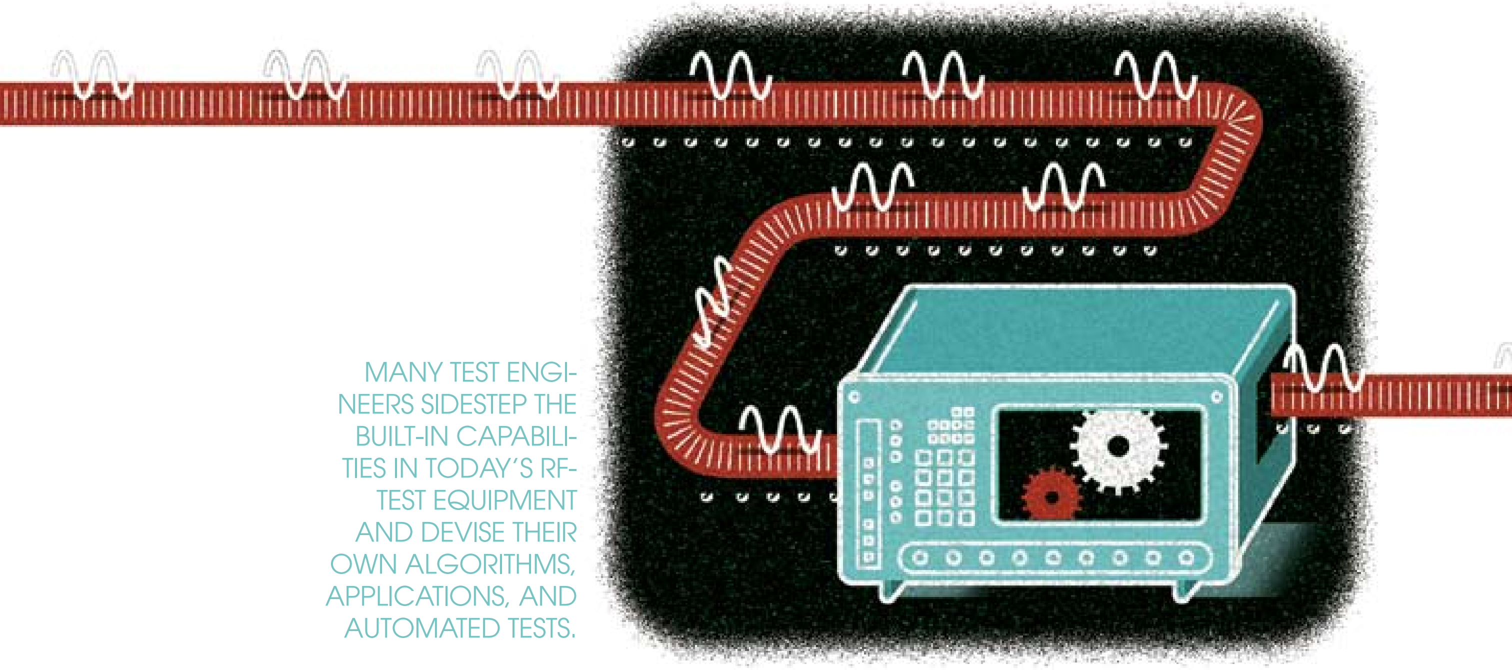

MANY TEST ENGINEERS SIDESTEP THE BUILT-IN CAPABILITIES IN TODAY'S RF-TEST EQUIPMENT AND DEVISE THEIR OWN ALGORITHMS, APPLICATIONS, AND AUTOMATED TESTS.

RF ENGINEERS AUTOMATE TESTS

BY MARTIN ROWE • SENIOR TECHNICAL EDITOR, *TEST & MEASUREMENT WORLD*

Testing of RF devices, such as amplifiers and RFICs (radio-frequency integrated circuits), can be tedious work. Such devices work over a wide range of frequencies and power levels, and they must meet specifications over temperature and power-supply ranges. Testing for all of those conditions can generate loads of data. Fortunately, automation can cut test time and help you make sense of all that information. You may have a spectrum analyzer, a network analyzer, or a power meter with features that can improve testing, but you may be unable to use the instrument if you must maintain compatibility with older models. If you're testing leading-edge RF products, your test equipment may lack the necessary dedicated features, and you'll have to develop your own.

Bill Drago, a test engineer at L-3 Communications' Narda Microwave East (www.nardamicrowave.com/east), supports production of RF amplifiers, downconverters, upconverters, and transceivers that operate in the C through Ka bands. These products often remain in production for years, which is the reason that Drago is unable to take advantage of features in newer test equipment that can automate many of the measurements he needs to make. He developed his tests before such automation was available, and he needs all of his test instruments to continue to follow identical procedures. Thus, he has written software that performs automated measurements, such as amplifier gain, 1-dB compression, IMD (intermodulation distortion), return loss, spurious noise, and noise figure. According to Drago, spurious-noise testing is important. "Downconverters and upconverters mix an input signal with a local oscillator," he says. "The converter's local oscillator must be tuned to customer specifications within a certain range and step size. The converter needs a frequency synthesizer that's programmable with specified steps over its frequency range. The frequency synthesizer can't introduce any spurs into the converter, so we must test for that."

To measure spurious noise, Drago uses an Agilent Technologies (www.agilent.com) spectrum analyzer to perform a frequency sweep through an approximately 1-GHz band around the carrier. He usually breaks that sweep into a number of smaller sweeps, each comprising 601 frequency points. Each step might be a few kilohertz wide. If Drago were to use one large sweep, its step size and the instrument's resolution bandwidth would be too wide and might miss a spur. He adjusts sweep span and resolution bandwidth so that spurs don't fall between the points in a sweep. Using a number of smaller sweeps is also faster than a single sweep for the bandwidth that Drago needs. He notes that a single sweep could take as long as an hour, depending on resolution bandwidth and frequency. Furthermore, smaller sweeps can reveal failures sooner than waiting for a large sweep to complete.

Although some of Drago's spectrum analyzers have built-in test applications for measuring spurious noise, he doesn't use them, because not all of his spectrum analyzers have that function. If he were to use that feature, he might not have a replacement instrument for the production line should that instrument fail. Instead, he wrote his own applications, and, by keeping the test applications outside the instrument, he can use any spectrum analyzer that's available.

Drago has written several other test programs, including one that measures an amplifier's 1-dB compression point. He builds this test into some of his VNAs (vector-network analyzers). The algorithm uses a binary-search process, similar to the type that SAR (successive-approximation-register) ADCs use. He starts with an input signal from an Agilent RF-signal generator that's the highest possible value for the amplifier under test. He then measures output power with an Agilent RF-power meter. If the output signal is compressed by more than 1 dB, he cuts the input signal in half and then increases it or decreases it by half of that value until he finds the 1-dB compression point (**Figure 1**).

FINDING HARMONICS

Michael Ford is a test engineer at Comtech PST (www.comtechpst.com), a manufacturer of RF amplifiers that operate at 500 MHz to 6 GHz at power levels of 100W to 10 kW. Ford's typical test station contains an RF-signal generator, a spectrum analyzer, a network analyzer, a power meter, and RF switches (**Figure 2**). A USB (Universal Serial Bus) digital-I/O module from Measurement Computing (www.measurementcomputing.com) controls the RF switches. The amplifiers mount on an environmental plate that changes their temperature. The test station measures gain, output power, harmonic distortion, IMD, efficiency, spurious noise, and harmonics.

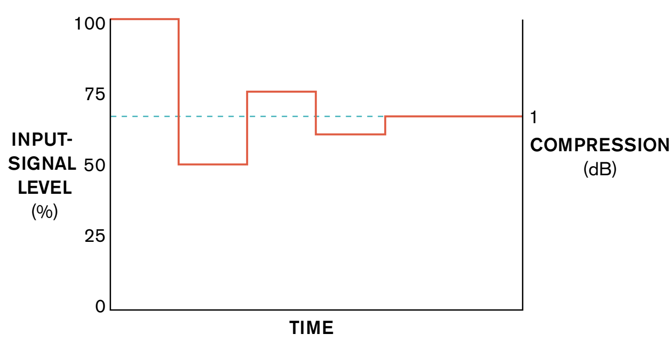

Figure 1 A binary-search algorithm finds an amplifier's 1-dB compression point (courtesy L-3 Communications).

On occasion, Ford uses an instrument's built-in functions. For example, he might measure spurious noise with an Agilent spectrum analyzer's built-in application. But he also writes his own applications to make those measurements if his instrument doesn't have that feature. Ford supports both engineering and production. When making measurements for engineering evaluations, he uses built-in functions, such as spurious noise and harmonic analysis. For production, Ford always uses his own software routines. "We write our own routines using a modular format because it lets us use equipment from multiple vendors, such as Agilent or Rohde & Schwarz [www.rohde-schwarz.com]. We use the same test routines and just change instrument-command libraries." For example, his routine for spurious-noise measurements works with spectrum analyzers from either manufacturer.

Ford's routines for measuring harmonics of a carrier frequency use variables for parameters such as center frequency, span, resolution bandwidth, and video bandwidth. After receiving those parameters, the routine runs sweeps at multiples of the carrier frequency to find the power of its harmonics. The results go to a spreadsheet for analysis.

CELLULAR NETWORKS

Although Drago and Ford must support products that remain in production for years, engineers developing tests for RFICs face different problems and have different reasons for not always using an instrument's automation features. Joe Flynn is a staff engineer at fabless-semiconductor company Sequoia Communications (www.sequoiacommunications.com). He evaluates RFICs that support several cellular-wireless standards (**Reference 1**). He has developed several test stations for evaluating the devices. "We characterize transceivers for gain, noise figure, IMD, cross-modulation, and EVM [error-vector magnitude]," he says. Flynn also develops his own automation tools, but measurement speed is the critical feature in choosing equipment. Because RFICs transmit and receive modulated signals, Flynn's test stations include spectrum analyzers for characterizing frequency content, and they include modulation analyzers for characterizing modulated content. **Figure 3** shows a system that tests the receivers in Sequoia's ICs. The receiver test bench lets Flynn evaluate how a receiver performs in the presence of undesired blocking signals, such as those from simulated cellular base stations, other cell phones, and broadcast-radio stations.

As part of the blocking-signal test, Flynn must measure SNR (signal-to-noise ratio) over a frequency range of 100 kHz to 12.7 GHz in 200-kHz steps. That

AT A GLANCE

- Testing over temperature and power-supply ranges can generate lots of information, and automation can help you make sense of it.
- Engineers may or may not use an instrument's built-in functions, depending on the needs of both their customers and the design teams within their companies.
- GPIB (general-purpose-interface-bus) communications are good for sending a series of short commands, whereas Ethernet works with the logic analyzer to collect data on digital-baseband signals.
- With loop-back testing, a manufacturer can wirelessly test a Bluetooth product as it moves along a production line.

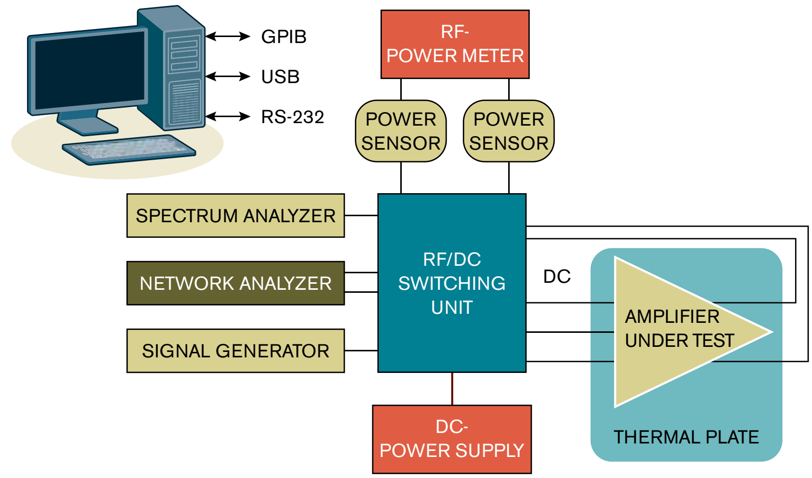

Figure 2 A typical automated tester for RF amplifiers uses a power meter, a spectrum analyzer, a network analyzer, and a signal generator (courtesy Comtech PST).

task takes approximately 60,000 measurements per channel, and the RFIC has 1300 channels over seven frequency bands. An SNR test generates loads of measurement data, and it's just one of many tests that Flynn must run on a preproduction lot of parts. To help analyze the data, Flynn developed a data converter that produces data plots. The tool lets him use production-test-analysis tools to view engineering data. For example, he might want to see the distribution of parameters, such as gain, return loss, and current consumption across the 100 parts in a preproduction run. "When we look at the data, we get a feel for how production parts will behave," he says.

Sequoia also developed an in-house Visual Basic Web-based tool that manipulates the bench-characterization data. The tool uses .netCharting (www.dotnetcharting.com) software to create some 1200 data plots on the parts. "When we have a test review, the tool lets us find any out-of-spec measurements," he says. The tool lets him select data parameters to plot and refine the data by selecting certain test conditions. For example, it lets him look at receiver gain and noise figure versus temperature or power-supply voltage.

Because he must make so many measurements, speed is key for Flynn when he selects a spectrum analyzer and develops a test method. To cut measurement time, he uses two Agilent MXA spectrum analyzers, one each for a receiver's in-phase and quadrature channels. The instruments are frequency- and phase-locked, which synchronizes the measurements. He then optimizes resolution bandwidth and sweep time to minimize test time: "When I started, a single SNR measurement on one channel at one blocker frequency took about a second. Now, I make each measurement in 18 msec." Flynn also learned how to minimize test time by using both LAN (local-area-network) and GPIB (general-purpose-interface-bus) communications. Most instruments in the test system use GPIB because, according to Flynn, "You can't beat GPIB when sending a series of short commands. The overhead needed to use Ethernet is apparent only when transferring large blocks of data." Thus, he uses Ethernet for the logic analyzer, which collects data on digital-baseband signals. He also uses a dedicated GbE (gigabit-Ethernet)-LAN card to avoid packet collisions between the test equipment and the corporate network. He uses three GPIB cards to cover all of the test equipment.

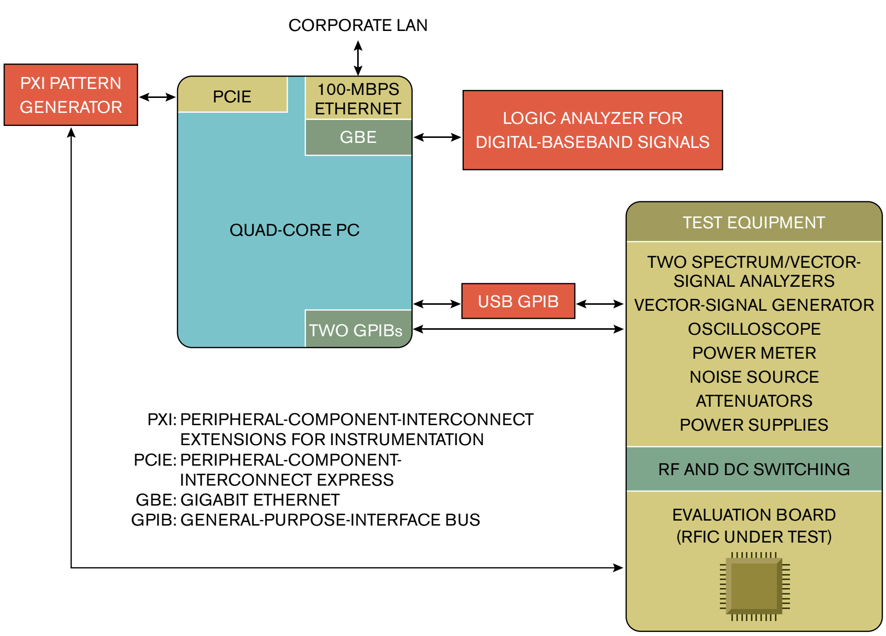

Figure 3 An RFIC-test station for testing receivers uses two GPIB cards and a LAN to communicate with instruments (courtesy Sequoia Communications).

MIX AND MATCH

CSR (www.csr.com) is a fabless-semiconductor company that develops wireless-communication RFICs for PANs (personal-area networks), such as Bluetooth and Wi-Fi. James Blackwell, who heads the company's applications-engineering group, helps customers evaluate CSR's RFICs and develop products based on the company's devices. CSR engineers use a mixture of in-house and purchased test equipment, usually starting with in-house testers. "Because we're often on the leading edge," says Blackwell, "we have to develop our own test suites until the test-equipment companies catch up." One example is a Bluetooth tester for performing loop-back tests. Blackwell notes that the Bluetooth specification defines a loop-back test in which the tester wirelessly controls the DUT (device under test). With loop-back testing, a manufacturer can wirelessly test a Bluetooth product as it moves along a production line.

When CSR's engineers several years ago developed a Bluetooth RFIC, engineers had to build their own RF-test system using RF-signal generators, spectrum analyzers, and vector-signal analyzers. They used The MathWorks' (www.mathworks.com) Matlab scripts to control the instruments, process the data, and produce test reports. In a loop-back test, the tester commands the DUT to produce a 2.405-GHz tone with a specified modulation signal, for example. The tester measures as many as 20 parameters, such as peak and average transmitted RF power. It also performs receiver tests, such as sensitivity and bit-error rate.

Some Bluetooth devices transmit at controlled power levels, so the DUT must operate in steps in its power table while the tester measures differences in power. It also measures frequency tolerance and drift. A test of the frequency response of the DUT's modulation filter uses 10101010 and 11110000 bit patterns. Over time, test-equipment makers developed Bluetooth testers, and CSR was able to use them. Today, the company's engineers use Bluetooth testers from Rohde & Schwarz, Agilent, and Anritsu (www.anritsu.com). CSR has all three instruments, so the engineers always have one that their customers use. That requirement is crucial when an engineer needs to reproduce a customer's test.

CSR engineers didn't immediately switch to a dedicated Bluetooth tester. "We work with the test-equipment manufacturers to develop test applications for their equipment," Blackwell explains. "But sometimes we must wait for a second or third generation of a tester before we can use it. Even after we adopt a commercially available tester, we may still use our own test suites for certain tests." Blackwell notes that dedicated Bluetooth testers may perform some tests faster or more accurately than CSR's in-house testers, but the company's engineers still use the in-house tester when they feel that it performs the tests better than a dedicated tester can.

TEST COMPANIES RESPOND

Despite the best efforts of test-equipment manufacturers, some engineers still often find that they need to develop their own test algorithms. Test-equipment makers point out that some tests require application software in the instrument to perform a test because you need real-time results.EDN

REFERENCE

1 Rowe, Martin, "The RFIC evaluator," *Test & Measurement World*, March 2009, pg 9, www.tmworld.com/article/CA6639373.

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