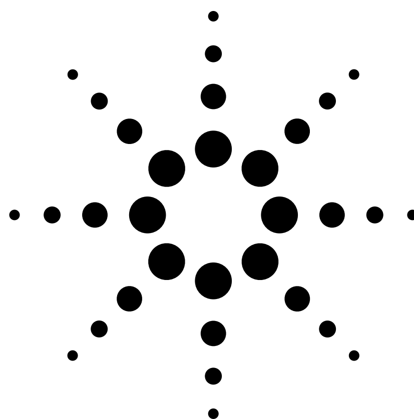
6 Hints for Enhancing Measurement Integrity in RF/Microwave Test Systems

Balancing the Tradeoffs Between Performance, Speed and Repeatability



Application Note 1465-18

Even though most RF and microwave test systems measure devices within a few broad categories—amplifiers, transmitters, receivers—every individual system faces a unique set of circumstances, requirements and challenges. As unique as each situation may be, three universal factors interact when you define any RF and microwave test system: performance, speed and repeatability. Within the unique situation each system developer faces, the ability to make tradeoffs between these factors is one key to achieving the required level of measurement integrity.

Opportunities to manage these tradeoffs can occur at many points along the pathways between the device under test (DUT) and the measurement instruments (Figure 1). This application note suggests a framework for those tradeoffs and offers six sets of hints that address common problems that may exist along RF signal pathways.

Hint 1 provides a foundation for all six hints. The remaining hints address the three major tradeoffs: Hints 2 through 5 can help you achieve greater performance, Hint 6 suggests several ways to improve measurement speed, and Hints 3 and 4 can help you enhance measurement repeatability. In general, these hints apply to signals in the range of 100 MHz to 26.5 GHz.

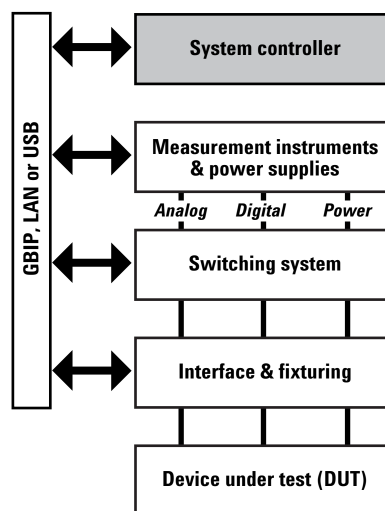


Figure 1. Within any test-system architecture, there are numerous opportunities to manage measurement integrity by balancing the tradeoffs between performance, speed and repeatability.

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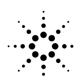

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Hint 1:
Prioritize performance, speed and repeatability

To lay the foundation for all six hints, it's essential to clarify our definitions of performance, speed and repeatability in this context. In most situations, one or two of these will be the dominant factor that drives your test requirements and your equipment choices. In all cases, a closer look at the interactions and tradeoffs between performance, speed and repeatability—as summarized in Tables 1 though 3—will help you manage your unique situation.

Building the foundation

Performance

In RF and microwave test equipment, Agilent's definition of "performance" focuses on instrument accuracy, measurement range and bandwidth. Instrument accuracy includes the specified absolute accuracy of amplitude and frequency measurements. Measurement range refers to dynamic range, distortion, noise level and phase noise, which are the attributes that enable precise characterization of signal levels. Bandwidth refers to the frequency width or data rate that can be processed and analyzed.

Speed

Test system speed or throughput depends on hardware, input/output (I/O) and software. Our focus is on the hardware and the four factors that influence speed: measurement set-up time, measurement execution time, data processing time and data transfer time. At RF and microwave frequencies, a key aspect of set-up time is the settling time of the DUT or the test system whenever a change is made (e.g., switch closures, power level, etc.).

Repeatability

For any test system, the ability to produce consistent results—test-to-test, day-to-day—is crucial. However, repeatability does not infer a high level of precision, which depends on the performance of individual instruments. Instead, repeatability means a consistent result, whatever the specified accuracy. For any given instrument, repeatability may be different for certain measurements or modes so it's important to check the product specifications or ask the manufacturer. To some extent, repeatability can be improved with more averaging or through modified algorithms that produce an accurate approximation of a standardized measurement. It can be optimized by minimizing changes to measurement settings such as center frequency, span and attenuation level.

Summarizing the interrelationships

The test requirements and business drivers for a DUT will help you assess the relative importance of performance, speed and repeatability. Once you've identified the dominant factor and the intensity of its requirements, it becomes easier to sort through the interactions and their impact on the system. Tables 1, 2 and 3 summarize the implications of these interactions in two cases: when the intensity of the dominant factor is either high or low.

Table 1: When performance dominates, the most important interaction is between performance and speed.

Performance Requirements	Implications for Speed	Implications for Repeatability
Low	Can go faster: Will spend less time on tasks such as instrument calibration and measurement averaging.	Probably lower: This situation suggests low performance equipment, which may yield greater uncertainty and, therefore, less consistency from test to test.
High	Must go slower: Will probably need to spend more time on tasks such as instrument calibration, path correction and error removal to ensure greater precision.	Probably greater: High performance equipment with lower noise floor, fewer distortion products, greater isolation, and so on, will tend to provide less uncertainty and greater measurement consistency.

Table 2: When speed dominates, the key relationship is between speed and repeatability

Speed Requirements	Implications for Performance	Implications for Repeatability
Low	Greater precision: Can spend more time on calibration, path correction, error removal, etc. However, this situation may suggest lower-cost instruments, which often have fewer performance-enhancing features.	Greater consistency: Can increase the number of averages, number of samples or sweep time (with average detectors). May be able to use methods such as long RMS detection, narrow video bandwidth or precise, time-intensive algorithms.
High	Lower precision: The need for speed may lead to compromises such as less accurate measurement techniques, lower measurement resolution, fewer sweep points and faster sweep speeds.	Lower consistency: Less time available for measurement averaging and intricate, precise algorithms may mean greater uncertainty and lower consistency.

Table 3: When repeatability dominates, the key relationship is once again between repeatability and speed

Repeatability Requirements	Implications for Performance	Implications for Speed
Low	May be lower: Low repeatability implies a larger error budget, which may also infer lower-performance instruments (less absolute accuracy).	Can go faster: When repeatability has low importance, less time will be spent on improving measurement consistency.
High	Must be high: The need for high repeatability implies a smaller error budget, which probably infers higher-performance instruments (greater absolute accuracy, less uncertainty).	Must go slower: May need to increase number of averages, number of samples or sweep time (with average detectors) to reduce uncertainty and increase consistency. May not be able to use alternative algorithms (e.g., "fast ACP mode").

Repeatability and performance

In Tables 1 and 3 there is an important secondary relationship between repeatability and performance. This is an indirect relationship linked by measurement uncertainty. When dealing with uncertainty, some system developers create an “error budget,” the size of which depends on the margin between test requirements and system uncertainty. The two major contributors to uncertainty are absolute accuracy (instrument performance) and measurement consistency (repeatability). If the instruments in a system have high absolute accuracy, then there is a wider margin in the error budget for lower repeatability. If the instruments provide consistent results, that leaves more room in the budget for somewhat lower absolute accuracy.

Multiple “high” requirements

Satisfying requirements such as “high speed with high repeatability” or “high performance with high speed” will probably require sophisticated instrumentation that is somewhat more expensive than less-capable equipment. However, many high performance instruments may include hardware accelerators that speed up time-consuming operations such as averaging and calibration. Some models may also include multiple algorithms for calculating parameters such as adjacent channel power (ACP).1

If all three requirements rate “high” then every element of the system—test equipment, switching, cabling, connectors, etc.—must be scrutinized. The best solutions will likely demand a high price, but may provide additional capabilities and benefits.

1 As an example, some Agilent PSA series spectrum analyzers include a standard "ACP mode" and a "fast ACP mode." The fast mode provides an accurate approximation of the standard-compliant measurement.

Hint 2: Review the nature and behavior of the DUT

A typical automated test system performs three basic tasks: sourcing, measuring and switching. Decisions about which signal generators, power meters, spectrum analyzers, network analyzers, switch matrices and cables to use depend on the electrical and mechanical attributes of the DUT. At RF and microwave frequencies, a few essential characteristics require special attention.

Electrical parameters

The basic nature of the DUT is a key consideration: Is it passive and linear or active and nonlinear? Passive, linear devices are easier to deal with because they typically have fixed gain and phase shift at any allowed input power level across their operating bandwidth. In contrast, active devices demand greater care because they usually have a nonlinear operating region that is highly sensitive to input power, producing different results at different levels. Within a test system, this may suggest the addition of amplifiers or attenuators to precisely control power levels, and perhaps the addition of couplers to split off and verify the power level being delivered to the DUT. These additions should not be taken lightly: at high frequencies, every system element has a complex-valued impedance (with associated S-parameters) and every additional connection creates the possibility of undesirable interactions with the DUT.

- **Avoid mismatches:** An impedance mismatch at any connection can cause insertion loss, which robs power from any sourced or measured signal. As a truism, power is expensive at high frequencies—and it becomes more expensive if it has to be delivered across a wide frequency range. ***Hint:*** Use high precision cables and accessories, and fully characterize their actual impedance using a vector network analyzer (VNA), especially if the DUT is an active device.

- **Minimize VSWR:** The combination of a switch matrix, its connectors, its internal and external cables, and even the bending radius of any RF cables can induce errors caused by voltage standing waves in the DUT. ***Hint:*** To minimize this error, use a switch matrix with a voltage standing wave ratio (VSWR) specification of 1.2:1 or better.

- **Enhance isolation:** If your test requirements call for simultaneous measurements of high- and low-level signals then the isolation specifications of the switch matrix will affect measurement integrity. ***Hint:*** If there are multiple pathways through the DUT, use a signal generator and spectrum analyzer to characterize the isolation properties to the extent possible. If this can't be done then the system should be configured and programmed to route high- and low-level signals on non-adjacent pathways or through separate switch units.

Mechanical attributes

One set of details to consider is the number and type of connectors for signals and power (AC or DC). This will influence factors such as the required size of the switch matrix and the complexity of system cabling. ***Hint:*** Use a switch matrix with enough ports to let you make all system-to-DUT connections just once. This will minimize delays while waiting for signals to settle, and minimize the chances of damaging the switch matrix or DUT with sudden changes in power level.

Hint 3: Understand, characterize and correct RF signal paths

Without additional correction, product specifications extend only as far as the "calibration plane" that exists at an instrument's input and output connectors. To achieve accurate, repeatable measurements—and corrected DUT results—we suggest that you push the calibration plane out as close as possible to the DUT. There are several ways to achieve this, whether the pathways are passive or active and the DUTs are local or remote.

Handling passive pathways

Passive devices have fixed gain and phase shift at any allowed input power level across their bandwidth. However, every connection along a passive path may have an impedance mismatch, which will cause insertion loss and phase shifts (or delays). At high frequencies seemingly simple passive elements become complex transmission-line elements, precluding simple algebraic addition of losses and phase shifts along the path. ***Hint:*** Use a VNA to either measure the entire connected path or characterize the S-parameters of each element and use vector math to model the total loss and phase shift of the entire path. These values can be stored in the system PC and applied as needed to correct a measurement, or they can be applied by a network analyzer, for example, to enable real-time adjustment of filters and other variable DUTs.[2]

Correcting active pathways

The performance of active devices may vary with changing input power. The process required to improve measurement accuracy depends on whether the device is operating in the linear or nonlinear portion of its response. If an active device such as an amplifier is operating in its linear region—well below its 1-dB compression point—during both calibration and measurement operations, then corrections can be accurately applied at any power level within that region. ***Hint:*** If the active device is operating in the nonlinear portion of its response then the power level used for a measurement must also be used during calibration to ensure accurate correction. If measurements will be made at multiple power levels in nonlinear mode, then individual calibrations must be made at each of those levels and stored for later use.

Hint: Check the frequency response of the active device over the frequency range of the DUT. Again, you should either measure the entire path at specific power levels or characterize the S-parameters of each interface and use vector math to create a model that can applied after-the-fact or in real time.

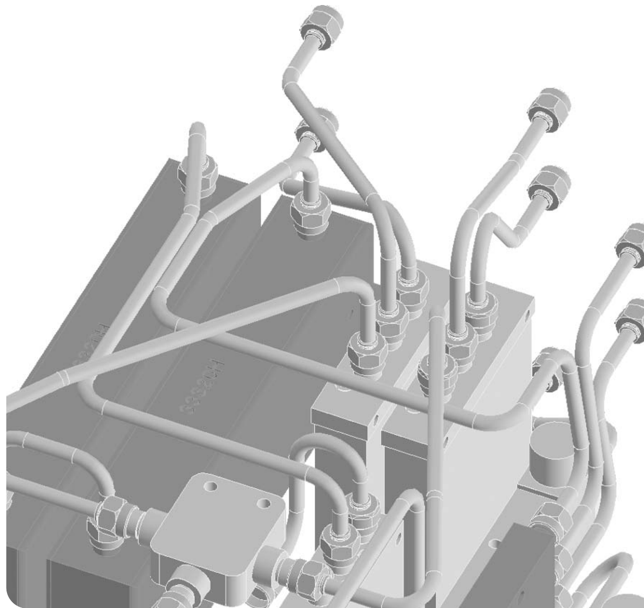
Hint: To simplify the process of characterizing and correcting RF signal paths, some system developers minimize the use of active devices. This reduces both the calibration effort and the chance of errors caused by variations in power level when operating in nonlinear mode.

Dealing with DUT distance—near or far

Accurate correction can be difficult whether the DUT is mounted in a fixture at the test system or located several yards away in a test chamber. Fixture-based measurements are challenging because pathways often include transitions from coaxial cables to microstrip-based shorts, opens and loads. ***Hint:*** If high quality microstrip elements are not available it will be necessary to measure the fixture with a network analyzer, model the impedance, and remove those effects from the measurements.

When the DUT is remote, the main issues are path attenuation in long cable runs and path variation due to temperature fluctuations and cable flexion. ***Hint:*** Characterize path attenuation either by measuring the entire pathway between the instrument and the DUT (if possible) or by measuring each element along the path and using vector math to combine their complex-valued responses.

2 To learn more about S-parameter measurements, please see Application Note 154, *S-Parameter Design,* and Application Note 1287-3, *Applying Error Correction to Network Analyzer Measurements.*



Hint 4: Be aware of everything connected to an instrument

Test equipment manufacturers specify the performance of every instrument up to the front-panel connectors that source and measure signals. From there, everything that comes between the instrument and the DUT can affect instrument performance and measurement repeatability. At RF and microwave frequencies and power levels, the three worst offenders are typically cables, switches and signal conditioners.

Selecting the right type of cable

When specifying a test system you will need to decide what type of cabling to use for device interconnection, and you may be able to specify the type used within the switch matrix. As a general rule, a stable cable will provide lower insertion loss, better VSWR and, therefore, greater measurement repeatability. At high frequencies, the three most commonly used types of cabling are semi-rigid, conformable and flexible.

Semi-rigid

As suggested by the name, these cables do not easily change shape, ensuring excellent performance and repeatability. High quality semi-rigid cables achieve additional stability during the manufacturing process through techniques such as MIL-standard temperature cycling. When applied after the forming process, temperature cycling can eliminate internal stresses that may cause later deformation of the preformed cable.

The quality of the dielectric used in these cables also affects their measurement performance. Solid Teflon is the most common but contributes to insertion loss. Expanded Teflon is currently the best alternative, providing lower insertion loss and wider frequency range. All of this attention to detail is reflected in the cost of these cables, which is considerably higher than conformable or flexible cabling.

Conformable

These cables offer less stability than semi-rigid cables because they are easily shaped and reshaped. Their flexibility affects measurement repeatability and long-term reliability.

Flexible

Sometimes called “instrument-grade cables,” these typically offer good phase stability and low insertion loss but at a relatively high price. They also tend to be high maintenance, requiring careful handling because severe deformation can alter their electrical properties and cause inaccurate measurement results.

Avoiding switch-related problems

Switching is central to overall system functionality, automating the connection of signals and power supplies between instrumentation and the DUT. Because most sourced and measured signals pass through the switch matrix, any shortcomings in its specifications can affect measurement performance, speed and repeatability. At high frequencies, three specifications are particularly important: isolation, VSWR and insertion loss.[3]

- **Maximize isolation:** Leakage between signal paths can make it very difficult to measure low-power signals in the presence of one or more powerful signals. (This is most likely to occur when high- and low-power signals are routed through a switch matrix simultaneously.) ***Hint:*** Choose a switch with isolation specifications of 90 dB or better. This will reduce leakage and potentially minimize the need to route signals through physically separate switch assemblies.

3 For detailed information, please see the *Agilent Custom Switch Matrices* product note, publication number 5966-2961.

4 Phase repeatability is another important specification to consider when making these measurements.

- **Minimize VSWR:** High VSWR can cause phase errors and therefore affect the accuracy of vector and modulation measurements.[4] VSWR in a switch matrix is directly related to the VSWR of the coaxial switches used within the matrix, and the VSWR of an individual switch depends on its mechanical dimensions and tolerances. ***Hint:*** You can further minimize VSWR by using cables that are short compared to the required bandwidth. If this is not practical—due to wide bandwidth or mechanical requirements—then the best alternative is to add insertion loss to the transmission lines via pads or lossy cables. This will reduce the amplitude of VSWR-induced ripples over the frequency range of interest, but at the expense of higher overall insertion loss.
- **Manage insertion loss:** This tends to become a problem at higher frequencies and is typically specified versus frequency in tabular or equation form. ***Hint:*** As a switch ages, its insertion loss may change so look for specifications such as "insertion loss repeatability" or "insertion loss stability" that are valid through the end of the product's expected lifetime. Knowing this type of worst-case value can help you manage your error budget.

Evaluating signal conditioners

As described in Hint 3, the DUT, its test requirements and its location may dictate the insertion of passive or active signal conditioners into the signal paths. These can be standalone devices or may be built into the switch matrix. Amplifiers, attenuators and frequency converters are the most commonly used signal conditioning devices.

Amplifiers

A signal might need additional gain if a precise amplitude measurement is required or if it is being sent over a long cable run. Several key specifications will help you determine an amplifier's suitability for your application.

- **VSWR:** Amplifiers are notorious for having poor VSWR. ***Hint:*** Alleviate VSWR problems by connecting an attenuator or an isolator (though these have limited bandwidth) to the amplifier output.
- **Intermodulation:** Amplifier bandwidth is important when measuring intermodulation distortion or spurious signals outside the bandwidth of the DUT. ***Hint:*** Beware of amplifiers with poor dynamic range or a low 1-dB compression point, which can produce enough intermodulation distortion to affect harmonic measurements in the presence of a strong fundamental.
- **Spurs:** Switching power supplies may cause spurs that are related to the switching frequency, which is typically 100-200 kHz. ***Hint:*** Avoid using amplifiers—or any other devices—that contain switching power supplies.

Attenuators

Electromechanical and electronic designs provide different levels of flexibility and precision in managing signal levels. Electromechanical attenuators use discrete switches that typically provide stepped resolution of 1 or 10 dB. Electronic attenuators provide virtually continuous settings with 0.1- or 0.25-dB resolution; however, those that use PIN diode-type switches can produce "video leakage" spikes that may contaminate measurement results. ***Hint:*** Cascade electromechanical and electronic attenuators as needed to provide greater control of attenuation.

Hint: Pay attention to the plating material used on attenuator connectors. As an example, nickel becomes non-linear at high power levels and will cause intermodulation distortion. Instead, choose a higher quality conductor such as gold.

Frequency converters

When the DUT is remote from the test system, you can reduce insertion loss in long cable runs by using a downconverter to shift signals to a lower frequency range. ***Hint:*** At the test system, upconversion can be used to restore the signal to its original frequency, but it may be necessary to also apply filtering to remove unwanted frequency components created during the conversion processes.

Hint: If multiple signals, paths or conversions are used when making vector or modulation measurements, some form of phase locking must be used to ensure accurate results. You can do this by connecting the instruments and frequency converters to a common frequency reference and then measuring the phase of each signal relative to the reference signal.

Hint 5: Examine the operational attributes of switches

When deciding what type of technology to use in a switch matrix, it can be helpful to go beyond the electrical performance and look at operational attributes such as device longevity, power requirements and fail-safe operation.

Electromechanical versus electronic

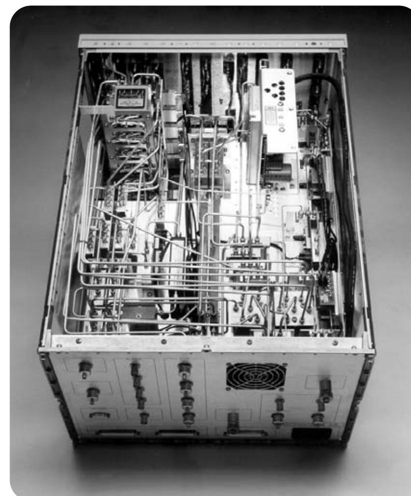
With numerous moving parts and physical contacts, electromechanical switches tend to suffer from relatively rapid degradation, declining repeatability and limited life. In contrast, electronic switches have no moving parts so offer longer life and greater repeatability. In practice, the best choice depends in part on the actual number of switching cycles a system will require: consider the number of closures per test, the number of tests per day, the expected lifetime of the system and so on.

Another practical consideration is the power level of the routed signals. Switching of high power signals will damage most switches, lowering repeatability and shortening lifetime. ***Hint:*** To prevent the premature demise of either electromechanical or electronic switches, program the system instrumentation to reduce signal levels before opening or closing any switches in the matrix.

Latching versus non-latching

Internally, electromechanical switches use either latching or non-latching relays. Most latching types need a 100-200 msec pulse of DC power to open or close the relay.[5] Non-latching switches require constant power—typically 24 V at 200 mA—to maintain contact. In a large switch matrix non-latching switches can generate enough heat within a system rack to affect measurement performance. ***Hint:*** If you choose to use non-latching switches, check the actual heat rise and be prepared to include additional cooling in the system rack.

Hint: It's essential to know how either type of switch will behave after a power failure or emergency shutdown. For maximum safety, select a switch matrix that returns to a known condition or configuration when power is restored. Non-latching switches are often the default fail-safe choice because they open when power is removed and won't close again until power is applied by the test program. However, latching switches can be made fail-safe if they include hardware and firmware that will latch them into a safe mode at power down.



Advanced features: Built-in signal conditioning

One advantage of having a switch matrix in a system is that signal conditioning can be built into the matrix by the manufacturer. As an example, Agilent's custom switch matrices can be configured with a variety of devices: amplifiers and attenuators; filters and isolators; and phase- and frequency-translating devices such as mixers, doublers, and dividers. These devices are permanently connected with semi-rigid coaxial cables and no additional external cabling is needed. The result is a compact, convenient, one-box solution.

5 *Another hint:* To minimize power requirements, some developers program the system to actuate these switches serially or in small batches, though this causes longer total switching time

Hint 6: Accelerate measurement set up and execution

Whether you gauge system performance as “devices tested per unit of time,” “tests per unit of time” or another time-based metric, measurement speed depends on two essential factors: the time required to set up the system and the time required to perform the measurement. The three major elements of any system—hardware, I/O and software—can help or hinder both processes. Agilent Application Note 1465-7, *Maximizing System Throughput and Optimizing System Deployment,* offers several useful tips about software design, system I/O and low-frequency instrumentation. To complement that material, this hint adds new information specific to RF/microwave instruments and systems.

Fine tuning individual instruments

Any configurable device used in a system can become a bottleneck that limits measurement speed. The latest generations of RF/microwave instruments—signal generators, power meters, spectrum analyzers and network analyzers—offer flexible features and capabilities that can minimize bottlenecks and enhance system performance.

Signal generators

Many of these are available with built-in modulation and arbitrary waveform capabilities, potentially reducing the number of instruments in a system, simplifying system cabling and lessening software complexity. ***Hints:*** Instrument configuration may be somewhat complex and time consuming, but you can significantly reduce test time by creating states ahead of time, saving them in memory and then programming the system to recall the saved states as needed. If the system needs to load arbitrary waveform data during a test, download the minimum number of points and use binary format rather than ASCII.

Power meters

The biggest potential time savings come from models that offer built-in calibration capabilities that extend the cal interval from hours to months. ***Hint:*** Use digitizing power meters that offer wide video bandwidths and fast data sampling. Some of these units can generate 1000 or more corrected readings per second, improving measurement accuracy and repeatability through averaging.

Spectrum analyzers

With any spectrum analyzer, the three key adjustments are frequency span, points per measurement and resolution bandwidth (RBW). ***Hints:*** Using the fewest necessary points and the widest possible RBW is the easiest way to reduce measurement time. Utilize a current-generation spectrum analyzer that automatically speeds things up by switching to Fast Fourier Transform (FFT) mode when measuring narrow spans.

Hint: To gain maximum benefit, use automatic input ranging selectively. When used to measure signals of rapidly varying amplitude, auto ranging may frequently change the input attenuator settings and slow the measurement. However, if signal levels are low and relatively constant, auto ranging can improve the signal-to-noise ratio and also shorten measurement time by allowing use of wider span and RBW settings.

Network analyzers

Calibration of VNAs can be very time consuming, especially the manual connection of shorts and standards. ***Hint:*** Agilent’s line of electronic calibration or “ECal” modules automates this process, offering faster and more repeatable calibrations on one to four ports through a single connection. This method also reduces wear on test-port connectors and calibration standards.

Hint: The application of correction data is usually faster when performed inside the analyzer rather than externally in the system controller. With most VNAs you can save the calibration curve for a specific test and recall it as needed. One note: This method is more effective when used over a series of somewhat narrow frequency spans than with one extremely wide measurement span.

Shaping the future of test system development

Every test system faces a unique set of challenges, but in all cases the ability to manage the direct and indirect tradeoffs between performance, speed and repeatability will help you achieve the required level of measurement integrity. The ability to manage crucial tradeoffs also applies to the selection of instrumentation, I/O connections and software elements for your test system. Agilent is helping reduce the number of compromises you have to make by offering system-ready instrumentation, PC-standard I/O and open software environments. By creating complementary system elements and supporting continually advancing standards such as LAN, Agilent can help you optimize—and even maximize—system performance now and in the future.

To discover more ways to accelerate system development, simplify system integration and apply the advantages of open connectivity, please visit the Agilent Open Web site at **www.agilent.com/find/open.** Once you're there, you can also sign up for early delivery of future application notes in this series. Just look for the link "Join your peers simplifying test-system integration."

Related literature

The latest additions to the 1465 series of application notes provide a wealth of information about the successful use of LAN, WLAN and USB in test systems:

- *Using LAN in Test Systems: The Basics,* AN 1465-9 (pub no. 5989-1412EN) **http://cp.literature.agilent.com/litweb/pdf/5989-1412EN.pdf**
- *Using LAN in Test Systems: Network Configuration,* AN 1465-10 (pub no. 5989-1413EN) **http://cp.literature.agilent.com/litweb/pdf/5989-1413EN.pdf**
- *Using LAN in Test Systems: PC Configuration,* AN 1465-11 (pub no. 5989-1415EN) **http://cp.literature.agilent.com/litweb/pdf/5989-1415EN.pdf**
- *Using USB in the Test and Measurement Environment,* AN 1465-12 (pub no. 5989-1417EN) **http://cp.literature.agilent.com/litweb/pdf/5989-1417EN.pdf**
- *Using SCPI and Direct IO vs. Drivers,* AN 1465-13 (pub no. 5989-1414EN) **http://cp.literature.agilent.com/litweb/pdf/5989-1414EN.pdf**
- *Using LAN in Test Systems: Applications,* AN 1465-14 (pub no. 5989-1416EN) **http://cp.literature.agilent.com/litweb/pdf/5989-1416EN.pdf**
- *Using LAN in Test Systems: Setting Up System I/O,* AN 1465-15 (pub no. 5989-2409) **http://cp.literature.agilent.com/litweb/pdf/5989-2409EN.pdf**
- *Next-Generation Test Systems: Advancing the Vision with LXI,* AN 1465-16 (pub no. 5989-2802) **http://cp.literature.agilent.com/litweb/pdf/5989-2802EN.pdf**
- *Optimizing the Elements of an RF/Microwave Test System,* AN 1465-17 (pub no. 5989-3321) **http://cp.literature.agilent.com/litweb/pdf/5989-3321EN.pdf**

Earlier notes in the 1465 series provide hints that can help you develop effective low-frequency test systems:

- *Introduction to Test System Design,* AN 1465-1 (pub no. 5988-9747EN) **http://cp.literature.agilent.com/litweb/pdf/5988-9747EN.pdf**
- *Computer I/O Considerations,* AN 1465-2 (pub no. 5988-9818EN) **http://cp.literature.agilent.com/litweb/pdf/5988-9818EN.pdf**
- *Understanding Drivers and Direct I/O,* AN 1465-3 (pub no. 5989-0110EN) **http://cp.literature.agilent.com/litweb/pdf/5989-0110EN.pdf**
- *Choosing Your Test-System Software Architecture ,* AN 1465-4 (pub no. 5988-9819EN) **http://cp.literature.agilent.com/litweb/pdf/5988-9819EN.pdf**
- *Choosing Your Test-System Hardware Architecture and Instrumentation,* AN 1465-5 (pub no. 5988-9820EN) **http://cp.literature.agilent.com/litweb/pdf/5988-9820EN.pdf**
- *Understanding the Effects of Racking and System Interconnections,* AN 1465-6 (pub no. 5988-9821EN) **http://cp.literature.agilent.com/litweb/pdf/5988-9821EN.pdf**
- *Maximizing System Throughput and Optimizing System Deployment,* AN 1465-7 (pub no. 5988-9822EN) **http://cp.literature.agilent.com/litweb/pdf/5988-9822EN**
- *Operational Maintenance,* AN 1465-8 (pub no. 5988-9823EN) **http://cp.literature.agilent.com/litweb/pdf/5988-9823EN**

Appendix

Recapping Application Note 1465-17

Optimizing the Elements of an RF/Microwave Test System

When creating an RF/microwave test system, the technical and business factors associated with your DUT will help you choose the optimum combination of system hardware, I/O and software. Current and future developments in all three areas will also influence your choices.

Reviewing the essential considerations

Technical factors include the general and specific attributes of the DUT. Significant general factors include the complexity of the device, its stage in the product lifecycle and the nature of the manufacturing process. Specific electrical and physical attributes include the required frequency range, bandwidth and resolution as well as the number of ports or test points and changes in access to both as the device is assembled.

Budget and timeline are crucial business factors in the present. Looking to the future, consider the expected lifespan of both the DUT and its test system. For RF/microwave test systems there are two large classes of DUTs that have specific future requirements: long-lived DUTs such as aerospace and defense systems, and short-lived DUTs such as rapidly evolving commercial wireless products. The ability to meet the needs of either one long-lived DUT or multiple short-lived DUTs (through system reuse) improves when the test system includes long-lived hardware, I/O and software.

Translating requirements into optimized choices

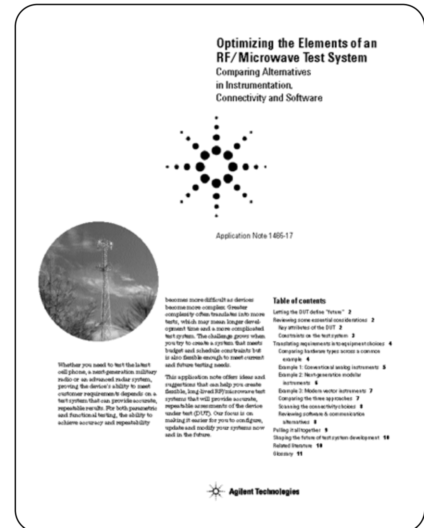
With the essential attributes and constraints in mind, the next step is translating those requirements into an efficient combination of hardware, I/O and software.

Hardware

Three hardware architectures can be utilized: “conventional analog,” “next-generation modular” and “modern vector.” Conventional analog instruments may enable faster system development because they are often the first to offer new levels of performance and are also familiar to many system developers. Next-generation modular instruments offer tremendous flexibility and potentially greater system longevity; however, these currently require longer development time and higher software costs. Modern vector instruments rely on DSP technology to provide the strongest combination of functionality, versatility and accuracy. The ability to expand their capabilities via firmware updates is an advantage when testing devices that include evolving communication standards.

I/O

Spurred by the PC industry’s steady advances in LAN performance (and commitment to backward compatibility) the trend in test equipment is toward greater use of the future-proof LAN interface while continuing to support GPIB.


Optimizing the Elements of an RF/Microwave Test System
Comparing Alternatives in Instrumentation, Connectivity and Software

Application Note 1465-17

Whether you need to test the latest cell phone, a next-generation military radio or an advanced radar system, proving the device's ability to meet customer requirements depends on a test system that can provide accurate, repeatable results. For both parametric and functional testing, the ability to achieve accuracy and repeatability becomes more difficult as devices become more complex. Greater complexity often translates into more tests, which may mean longer development time and a more complicated test system. The challenge grows when you try to create a system that meets budget and schedule constraints but is also flexible enough to meet current and future testing needs.

This application note offers ideas and suggestions that can help you create flexible, long-lived RF/microwave test systems that will provide accurate, repeatable assessments of the device under test (DUT). Our focus is on making it easier for you to configure, update and modify your systems now and in the future.

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Software and communication

The combination of application development environment (ADE) and instrument communication method creates tradeoffs between development time, software reuse and system performance. Graphical ADEs use a schematic approach that engineers tend to learn easily. Instrument communication has been evolving, with direct I/O and vendor-specific commands giving way to industry-standard command sets and instrument drivers.

Pulling it all together

When creating a new test system, consider vector instruments, LAN-based I/O, graphical programming and instrument drivers. This combination provides a highly future-proof system that should be easy–and cost-effective–to modify in the near-term, and maintain and update in the future. If you are required to comply with NxTest, then substitute modular instruments for vector instruments.

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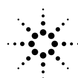

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