Don’t Stop with S-Parameters:

5 Essential VNA Measurements for Modern RF Devices

As devices become more highly integrated, complete characterization requires more than simple S-parameters. In the past, engineers needed a network analyzer for S-parameters, an oscilloscope for time domain, a spectrum analyzer and signal generator for spur and harmonic measurements, and pulse generators and pulse modulators for pulsed-RF measurements. Rather than using different dedicated instruments for each type of measurement, it’s best to use one flexible instrument that can perform all of your measurements on a single connection.

Measurements that engineers once considered advanced are now becoming common across every RF industry. This white paper goes over some of the critical vector network analyzer (VNA) measurements you must master to prepare for the next generation of RF devices:

- time domain
- multiport
- spectrum analysis
- mixer / converter test
- pulsed-RF measurements

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Time Domain

As the bit rates of digital systems increase, you need both time domain and frequency domain measurements to get a complete view of your device's performance. Rather than switching between a network analyzer and an oscilloscope, use the network analyzer's time domain application for both time and frequency domain measurements on a single connection. The network analyzer performs measurements in the frequency domain, then uses a fast Fourier transform algorithm to display the data in the time domain.

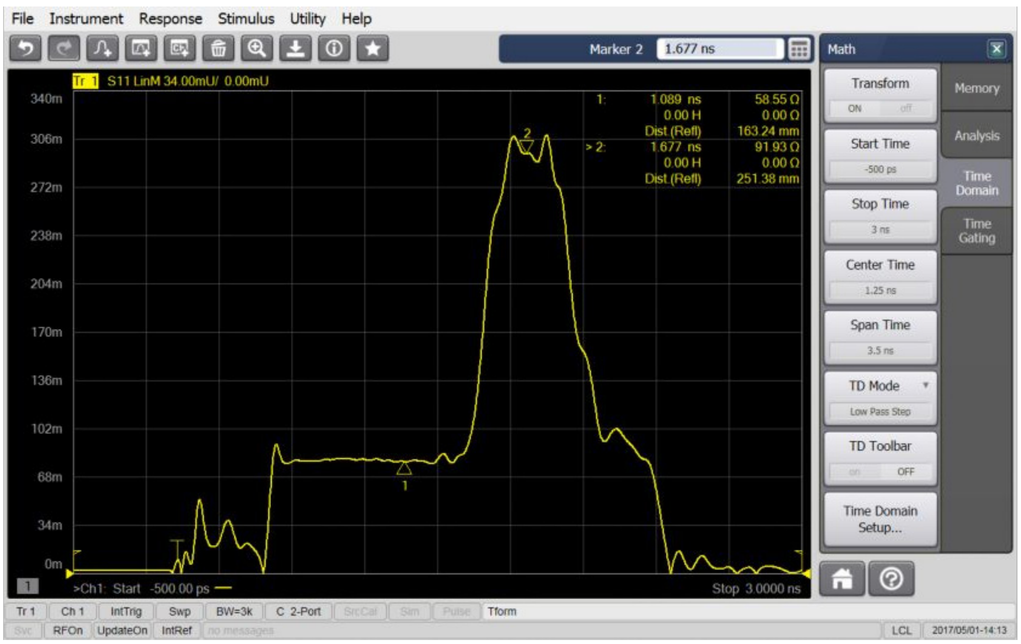


Figure 1. Time domain response on a USB VNA

Time domain data unlocks a new perspective on your devices. In the frequency domain, mismatches cause ripples throughout the whole response. It's impossible to tell precisely where the reflections are occurring in your device or cable. The time domain response (Figure 1) shows discrete discontinuities for each mismatch, enabling you to map the results to your device.

For high-speed digital interconnects like USB and HDMI, you need to verify bit transmission through the device. Enhanced time domain analysis on network analyzers provides eye diagram and mask tests with industry-standard patterns (pseudorandom binary sequence, K28.5) or user-generated patterns. You can even add jitter and measure powered devices to see real-world operation. You can do all of this analysis without an oscilloscope or pulse pattern generator.

Multiport

RF engineers often test devices with more than four ports. Front-end modules for multiband operation and multiple-input / multiple-output antennas require multiport characterization. Traditional multiport solutions involve a dedicated switch matrix. The switches route the test signal from the network analyzer's test ports to each port on the device under test (DUT). While switch-based multiport setups provide the port count, one trade-off remains — accuracy.

The VNA cannot entirely error correct for the switches because they sit beyond the VNA's directional couplers, which sample the test signals. Calibration can help, but a switch matrix can never achieve the dynamic range, temperature stability, and trace noise performance of a standalone VNA. With many multiport devices operating in the millimeter-wave frequency range, you need to mitigate small errors before they cascade into big problems at high frequencies.

Figure 2. Eight-port, 53 GHz VNA made of two Keysight P5028 USB VNAs

For accurate multiport measurements, you should use more network analyzers, not just more ports. You can cascade Keysight's USB VNAs for multiport operation, providing up to 12 ports at 20 GHz or up to eight ports at 53 GHz (Figure 2). The multiport configuration provides the accuracy you need for next-generation measurements using your existing VNAs instead of a dedicated multiport setup.

Spectrum Analysis

Traditional mixer and frequency converter characterization requires a network analyzer for frequency response measurements, as well as a signal generator and a spectrum analyzer for spurious emission (spur) measurements. With the wide bandwidths of modern RF applications, searching for spurs over a device's entire operating range delays the measurement workflow.

Fixtured spectrum analysis

Automatic fixture removal (AFR) provides a simple wizard to follow for characterizing and de-embedding fixtures. Once you have characterized your fixtures, you can de-embed them from your spectrum analysis measurements.

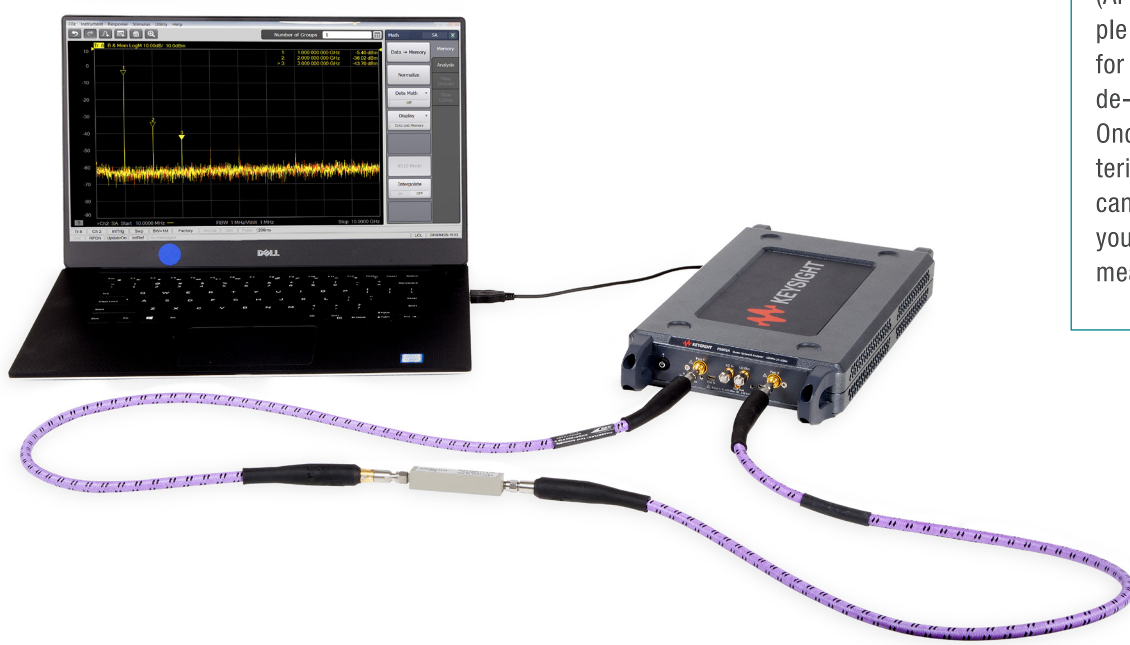
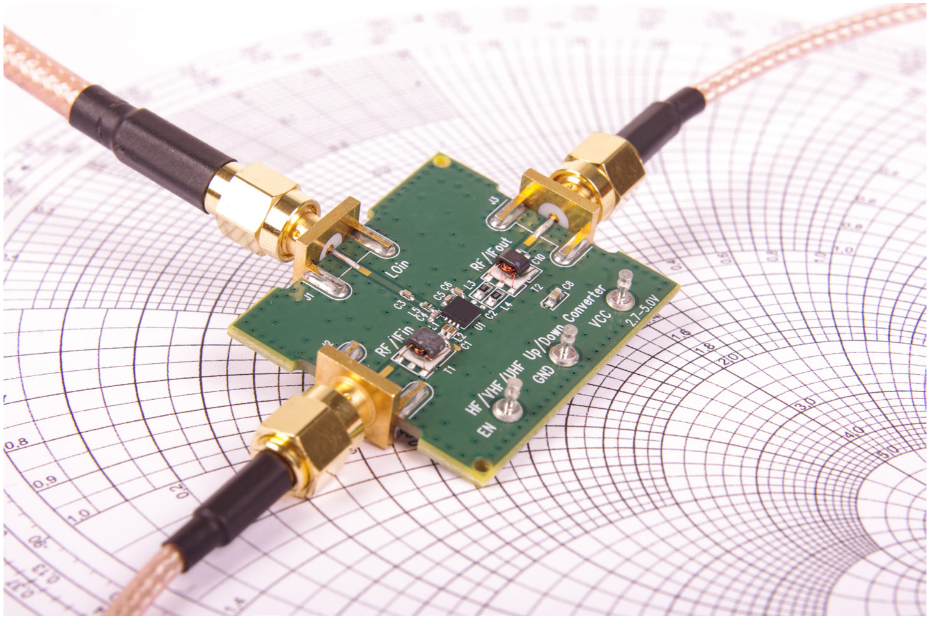


Figure 3. Spectrum analysis on a USB VNA

You can skip multi-instrument measurement setups and tedious spur searches by performing spectrum analysis on your network analyzer. Modern network analyzers contain powerful processors, accurate sources, and excellent receivers. These features make network analyzers versatile enough to provide fast and accurate spur searches. In addition to saving measurement time, you also save setup time by not needing to configure additional hardware such as signal generators, spectrum analyzers, and switches.

Mixer / Converter Test

If you can move spectrum analysis measurements to your network analyzer, it makes sense to perform the rest of your mixer measurements with your network analyzer. Setting up your fixtures and calibrating your test setup for a highly integrated DUT takes so much time that you should only do it once. Modern mixers may not even have an accessible local oscillator, making traditional measurements impossible.



Take advantage of your network analyzer's capabilities to make mixer measurements fast and accurate. You can quickly master both scalar and vector mixer measurements with wizards to guide you through gain / loss, group delay, and phase measurements. Performing mixer measurements on your network analyzer simplifies your workflow and provides unparalleled insights into your DUT's performance with vector-calibrated accuracy. With the high frequencies and tight margins of modern RF designs, you need results you can trust.

Pulsed-RF Measurements

Network analyzers typically stimulate DUTs with swept continuous-wave (CW) signals. However, you cannot characterize devices that are not meant to work in CW applications with a CW signal. In fact, CW signals can overheat and damage components designed for pulsed operation. One of the most prominent examples of pulsed-RF technology is radar communication systems. Because the radar systems operate on pulses, they require pulsed-RF measurements to test their real-world operation. You can't easily repair a radar circuit once you have deployed it, so you need to be certain that your tests are thorough and accurate.

Now you can seamlessly switch between CW and pulsed-RF measurements without additional hardware. Modern network analyzers contain pulse generators and modulators, providing a complete pulsed-RF solution in one box. As with spectrum analysis and mixer measurements, the integrated pulsed-RF measurements take advantage of the network analyzer's exceptional measurement performance to provide wide dynamic range, even on pulses as narrow as 1μs.

Beyond S-Parameters

RF devices are becoming more complex, but that does not mean that your testing needs to be complicated. Highly integrated VNAs take the effort out of testing highly integrated DUTs. With built-in functionality and wizards to guide you through complex tests, modern VNAs make complex characterization accessible to anyone.

The P50xxA series brings high-end performance and flexibility to portable USB VNAs. With a wide range of measurement applications, you can perform the measurements listed in this white paper and more. To learn more, visit keysight.com/find/usbvna.

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