With the trend towards adding more ports on components, accurate and fast multiport network analysis is required. Optimizing your vector network analyzer (VNA) configuration is critical to minimizing manufacturing cost-of-test. This application note provides an overview of multiport and multi-site test capabilities, how different multiport test solutions compare, and what considerations need to be made when configuring a multi-site test station.
# Table of Contents

Overview .......................................................................................................................... 3

The Expanding Need for Multiport Testing ................................................................. 4

Types of multiport solutions .......................................................................................... 5
  Simple switching test sets ......................................................................................... 5
  Full cross-bar switching test sets .............................................................................. 6
  Extension test sets ....................................................................................................... 7
  True multiport solutions ............................................................................................. 8

Comparing multiport solutions .................................................................................. 10
  Number of measurement sweeps .......................................................................... 10
  Dynamic range ........................................................................................................... 10
  Temperature stability ................................................................................................. 11

Multiport calibration .................................................................................................. 12
  Mechanical calibration ............................................................................................... 12
  Electronic calibration (ECal) ..................................................................................... 13

Multi-Site Techniques to Improve Throughput ......................................................... 15

Considerations when configuring multi-site solutions ............................................. 16
  Controller / CPU .......................................................................................................... 16
  Backplane speed and memory .................................................................................... 19
  PXI chassis .................................................................................................................. 19

Multi-display / multi-user ............................................................................................ 20
  Controller hardware .................................................................................................... 20
  Microsoft windows limitations ................................................................................... 21
  Minimizing operator control time with macros ........................................................ 22

Optimizing multiport testing with multi-site techniques ........................................... 22

Summary ....................................................................................................................... 23

References .................................................................................................................... 23
Overview

Driving down the cost-of-test is the key challenge in high-volume component manufacturing. With the trend towards adding more ports on components, accurate and fast multiport network analysis is required. Minimizing operator intervention, as well as reducing connection and calibration times, affects measurement throughput. Optimizing your vector network analyzer (VNA) configuration is critical to minimizing cost-of-test.

Modern instruments such as a multiport VNA using a PXI platform with state-of-the-art functions and capabilities are needed to improve measurement throughput of high-volume production testing. Keysight’s PXI VNA introduces many new capabilities that improve throughput while offering more flexible test configurations than conventional benchtop solutions. For multiport applications the PXI VNA offers a true multiport capability that allows test engineers to configure up to a 32-port VNA in a single PXI chassis. In addition, it enables multi-site or parallel testing in a reconfigurable form factor that is smaller than many conventional VNA box instruments.

This application note provides an overview of both multiport and multi-site capabilities. What are the different types of multiport test solutions and how do they compare? When configuring a multi-site test station, what considerations need to be made and what may affect your overall throughput? Throughout the application note the PXI VNA is introduced along with techniques for optimizing your test station.
The Expanding Need for Multiport Testing

In the early days of network analysis all measurements were focused on 2-port S-parameters. As the capabilities of VNAs expanded, the ability to test power splitters, mixers, differential devices, and more, led to the evolution of the 4-port VNA. Multiport is now considered to be any device that requires more than 4 ports for network analysis.

Today, many components include multiple functions integrated into a single component. The number of ports on these components continues to expand and increase in complexity. Examples include RF front-end module (FEM) that supports multi-band operations in smartphones, multiple-input / multiple-output (MIMO) antennas, and passive interconnect products for high-speed digital applications such as RF connectors or cable assemblies (Figure 1).

Figure 1. A wide variety of applications are driving the need for accurate multiport VNA measurements.

While some multiport devices may be tested only as a series of 2-port measurements, many applications require a more thorough multiport characterization of their devices. With an increasing number of measurement parameters for multiport devices, minimizing total test time is desired by high-volume manufacturers.
Types of multiport solutions
Various multiport measurement solutions are available depending on your performance needs, throughput requirements and budget.

Simple switching test sets
In the early days, component manufacturers already had either a 2-port or 4-port VNA, so it became a logical next step to add a series of signal routing switches to handle devices with more than 4-ports. As such, the native mode measurements of the VNA are sufficient and all that is required is RF switching to route the VNA ports to the various port pairs of the DUT.

This type of multiport solution uses 2-port measurements for each path from the common port so a 2-port VNA with one common port and one switch port can make all the required measurements. These are sometimes known as switching test sets or simple switch trees.

Switching test sets contain only RF switches formed in a matrix to provide the needed measurement paths. Figure 2 shows an example solution and block diagram of a simple switch tree test set. These test sets are typically constructed from either 1x2 RF switches or 1x4 to 1x6 RF switches. The 1x2 RF switches are sometimes used as some versions provide for an RF load on the unused ports. The 1x4 or 1x6 are typically mechanical switches and may not load the unused ports. If a multiport device has a path response between two ports that depends on the load match of a third port, the switch matrix must provide a load on the unused port. Larger switch configurations that have loads are often not available above 40 GHz, so 1x2 matrix arrays are used. Electronic 1x2 switches are available over a wide range of frequencies, but there are few electronic switches with higher port counts, so electronically switched test sets are typically configured from 1x2 RF switches.

Figure 2. Schematic of 2-port VNA with 24-port test set

The simple switch matrixes of Figure 2 can be viewed as having a port 1 switch set and port 2 switch set, and any path from port 1 side to port 2 side can be measured, but no measurements are available between ports on the port 1 of the test set, nor between ports on the port 2 side. Thus, while there are 24 ports available in the test set, only 12 paths can be measured from any one of the 12 input ports. Thus, this simple switch tree test set can support 144 paths, but a full 24 port device actually has 276 paths. There are 66 paths on VNA port 1 side that cannot be measured, and 66 paths on the VNA port 2 side that cannot be measured. To obtain a full matrix of paths, a so-call “full cross-bar” switch matrix is required.
Full cross-bar switching test sets

Many multiport devices require a measurement from each port to every other port, and in general the response of any path depends upon the loading or match applied to every other port. There is a further requirement on the full cross-bar solutions; a full N-by-N port calibration measurement must be performed to correct for the imperfect match at each port. This requires not only a full cross-bar matrix, but one that supports N-by-N calibration as well.

To accomplish full cross-bar testing, a configuration of a test set similar to the one shown in Figure 3 may be used. In the general configuration, sets of 1xn switch trees are cross connected to 1x2 switches at each port. This configuration provides for any path to be measured, but the unused ports are terminated back in the 1xN switches which are terminated internally in a load. If the 1xN switches are not internally terminated (rather, they are left open), then the 1x2 switch must provide a termination for an unused port.

Figure 3 shows a full cross-bar switch constructed of a 1x2 port switch connecting to a pair of the 1xN switches. With this configuration, every port that is not connected to the VNA is terminated in a switch load. However, it is difficult to use this type of switch matrix to perform full N-by-N calibrations as the exact value of the load termination of any port changes depending upon the switch settings of other ports.

![Examples of full cross-bar switching test sets](image)

For example, if test set ports 1 and 6 are the active ports, ports 2-5 are terminated in the 1x6 switch on the left. If test set port 5 is made active, then port 6 may be terminated in the 1x6 switch on the right. The fact that the termination of the port depends on the path selected makes calibration beyond the two ports selected more difficult. Custom switching test sets might have a reduced number of paths, forming a combination of full cross-bar on some ports and simple switch trees on other ports.

Either solid-state switches or electro-mechanical switches may be installed in a switch matrix depending on the performance required for the measurements. Solid-state switches are typically selected for high-volume testing where fast switching time and longer life time of switches are necessary, while electro-mechanical switches are adopted when handling high-power (i.e., > 1 W) for network analysis.
The combination of a VNA with switches is considered to be a low-cost solution to increase the number of ports on the VNA. However, because of the loss in the switches after the directional coupler associated with the VNA test ports, the system performance in terms of dynamic range, trace noise, or temperature stability is degraded compared to a standalone VNA. This degradation has a significant impact especially on higher-frequency applications above 10 GHz. These performance tradeoffs will be discussed in a later section of this application note.

Finally, the switch-based solution requires switching of signal paths for measurements using the VNA receivers (typically with two or four test ports), thus sequential measurements are necessary to obtain all the S-parameters of multiport devices under test (DUT).

Extension test sets

Extension test sets are an improved design for making full N-by-N calibrated measurements, as they include both directional couplers and switches. The extension test set extends the source switch matrix of the VNA to more outputs through a source switch and also extends the internal receivers to more ports through a receiver switch. This requires that an additional test port coupler be provided for each additional port. Because the switching occurs behind the VNA directional couplers, they are still available as test ports. The ports on the test set extend the total number of ports available. Figure 4 shows an example solution, as well as an example block diagram of an extension test set solution.

![Figure 4. Examples of extension test sets.](a) 16-port PNA solution with Model U3042A E12 extension test set. (b) Schematic of 4-port VNA with 12-port test set.
One key point of the block diagram is that the test set breaks into the source and receiver loops behind the test port coupler. Because any number of switch paths can be supplied behind the test couplers, there is in theory no limit to the number of ports that can be used. Further, this block diagram allows additional test sets to be added so that the any number of test ports can be created by stacking extension test sets. Common configurations are for a 4-port VNA to extend to a total of eight ports; 10-port extension test sets for a 2-port VNA to achieve a total 12 ports; and 12-port extension test sets for a 4-port VNA to achieve a total of 16 ports.

The switches may be either mechanical switches or solid state switches. Because all the switching occurs behind the test port couplers, the stability and performance of the measurements are much better than that of switching test sets, and loss in the switch, while it reduces the dynamic range, has no effect on stability of the measurements.

True multiport solutions

Today’s latest technology has led to the development of a multiport VNA solution that does not require external switching or additional couplers for multiport measurements. For example, the Keysight M937xA Series PXIe VNA is a full 2-port VNA that fits in one PXI slot and using multiple modules can be configured as a multiport VNA (Figure 5). Up to 16 M937xA modules can be configured using a single PXI chassis, making it possible to measure 32-port DUTs with full correction up to 26.5 GHz.
Multiport configurations of the M937xA use jumper cables that are connected between the modules in the same chassis for synchronizing signals (Figure 6). The 10 MHz frequency reference signal and trigger signal from the first module is distributed across all the PXI VNA modules. The local oscillator (LO) signal in the first module is distributed to each of the additional modules. In solutions above both 20 GHz and greater than 8 ports, it is recommended to split the LO output from the first module between the second module and the fifth module.

Figure 7. Jumper cables link 10 MHz reference and LO distribution in multiport configurations.

A key advantage of PXI-based instrumentation is that they are flexible, scalable, and re-configurable. This allows you to modify your test environment based on what you need and where you need it. In addition, if a PXI VNA module was to fail, spares could easily be kept to ensure manufacturing uptime.

Figure 8. PXI instrumentation allows easy modification of your test environment based on changing needs.
Comparing multiport solutions

Now that we have provided an overview of the different types of multiport solutions, let’s compare them in a few key areas. Compared to switch-based solutions, true multiport has more advantages for improving throughput of multiport network analysis. It provides higher performance by eliminating loss associated with switches, and faster speed with simultaneous data capture with multiple receivers.

Number of measurement sweeps

A 2-port VNA needs to make a forward and reverse sweep from both test ports for the most accurate measurements with full 2-port calibration. If a 4-port VNA is used, multiport error correction can be applied by making four measurement sweeps from each test port.

Figure 9 shows the number of measurement sweeps needed for total characterization of a multiport DUT. Because the true multiport-based PXI VNA captures data with multiple receivers, one for each test port, measurements can be completed much faster with significantly less sweeps compared to a switch-based solution. For example, with a 16-port device, a 2-port VNA using a full cross-bar switch matrix would require 240 sweeps to obtain 256 S-parameters, while a 16-port true multiport VNA would require only 16 sweeps. A dramatic reduction of the number of sweeps gives the PXI VNA-based true multiport solution a clear advantage in optimizing test times and throughput.

Figure 9. True multiport solutions complete measurements much faster, with significantly less sweeps, when compared to switch-based solutions.
Dynamic range

System dynamic range is defined as the difference between the max output power level from the source port and the minimum input power level that can be measured by the receiver. Switch-based multiport solutions degrade the VNA’s dynamic range due to the attenuation from the switches. A comparison of dynamic range for a true multiport VNA and switched test set based VNA is shown in Figure 10. As expected, a wide performance gap in the dynamic range is seen at higher frequencies with the true multiport VNA not having the effects of the test set switches.

Using a multiport test solution with a wider dynamic range is a key advantage because it allows a wider IF bandwidth (IFBW) to be selected to achieve the same trace noise. For example, if dynamic range is increased by 20 dB, then a 100-times wider IFBW can be selected, thus 100-times faster measurement speed can be achieved, with the same trace noise, to get the same measurement result.

Figure 10. True multiport VNAs offer a wider dynamic range due to the lack of degradation from the switch attenuation in a switched test set based VNA.
Temperature stability

If solid-state switches are installed in a switched test set based VNA, overall measurement performance is easily affected by temperature variation in the environment. Due to the drift error caused by the switches, it may be necessary to perform frequent calibrations to ensure the quality of calibration for multiport measurements.

Figure 11 shows the temperature stability performance of a true multiport VNA and a switched test set based VNA solution. A short calibration standard is connected to a test port on each of the systems, which were then placed into a temperature-controlled chamber where reflection measurements were performed. A reference measurement was made at 25 °C and then the ambient temperature in the chamber was moved to both 18 and 33 °C. Measured S11 magnitude data at each temperature is referenced to the first measurement at 25 °C. The VNA with the switch matrix has more than 50 mdB drift in 1 °C temperature change, while the true multiport VNA has a maximum drift of less than 5 mdB per °C.

The true multiport VNA solution eliminates the need for external switching, which can reduce or eliminate the need for periodic recalibration, thus dramatically reducing total measurement time.

![Graphs showing temperature stability performance](image)

Figure 11. By eliminating temperature stability drift errors caused by test set switching, true multiport solutions reduce or eliminate the need for periodic recalibration.
Multiport calibration

Calibrating multiport VNA test systems can be more time consuming and complicated than a standard 2- or 4-port VNA. For an N-port device, there are (N-1)(N)/2 possible paths, each one of which requires a 2 port calibration.

The standards for calibration come in two distinct types known as mechanical calibration standards and electronic calibration or ECal. Mechanical standards are physical representations of opens, shorts, loads, and in some cases thurs. For purposes of clarity, the word “thru” is used to describe a calibration kit through-standard; this is historically how the standard appears in VNA menus.

These are usually sold together as a set, and form a mechanical calibration kit or cal-kit as it is commonly called. Electronic calibration kits have built-in switchable standards that provide a similar function to the open/short/load standards, as well as a thru state.

Mechanical calibration

For anyone who has ever performed a calibration with mechanical standards, the thought of doing a 10- or 20-port mechanical cal sounds very cumbersome. The QSOLT calibration is a very convenient technique for simplifying multiport calibrations. The Quick Open Short Load Thru (QSOLT) calibration is a different blend between the SOLR (Unknown-Thru) calibration and the SOLT calibration. As the name implies, it requires an open/short/load one-port calibration and a defined Thru, but it is quick because the one-port calibration only needs to be performed on one of the test ports. In fact, any one-port calibration method can be used (such as offset short, or even ECal) on just one of the test ports, and then a defined Thru measurement is performed between ports 1 and 2. In this way, a full two-port calibration is easily performed on an insertable path using a Cal-kit that has one sex of standards.

If a multiport DUT has N ports, all of the same sex, one can create an N+1 test system, with a flexible cable on the extra port that matches the DUT connector. A simple one-port calibration on this extra port, plus a Thru connection to each of the other ports provides for a full N+1 port calibration. In this way none of the other ports need to move or even have calibration kits for them.

![Mechanical calibration kits](image)

Figure 12. Mechanical calibration kits contain individual standards to characterize systematic errors. Many of the kits include adapters for test ports and a torque wrench for proper connection.
Electronic calibration (ECal)

Today, modern versions of ECal use custom GaAs IC switches which provide an embedded nominal open, short, load and thru. These custom ICs may contain multiple short states in addition to the open state to ensure that a wide phase difference between standards is maintained over the entire frequency range. Because ECal modules contain solid-state electronic switches, they are very repeatable and stable.

From a specification or theoretical standpoint, the best TRL mechanical calibration kits provide the highest quality of calibration. Next are ECAL standards using the best ECal modules, followed by SOLT with sliding loads. Fixed load SOLT calibrations typically have the poorest performance.

In fact, if RF cables are used, the error from the cable flexure will undoubtedly cause sufficient errors in the TRL calibration to degrade its quality below that of the ECal. If one includes the likelihood of human handling error and added connector repeatability for mechanical calibrations, then there is little question that in practice, ECal modules almost always provide superior calibration to mechanical calibration kit methods.

Keysight offers 2-port ECal solutions with frequency coverage ranging from 300 kHz to 67 GHz and 4-port ECal solutions up to 26.5 GHz. It is interesting to note that for multiport calibrations the number of connections/disconnections do not change whether you are using a 2- or 4-port ECal. What does increase are the number of VNA button pushes during calibration. Figure 13 shows an example of how the multiport calibrations are done using a 10-port example with both a 2- and 4-port ECal. Note that both require 10 connections and disconnections.

![Figure 13. Electronic calibration simplifies multiport calibration while maintaining accuracy.](image-url)
Finally, it is possible to embed an ECal into a calibration switch matrix box and perform a user characterization at the end of each of the switch-matrix ports, such that the user characterization can provide calibrations at each of the ports. Figure 14 shows an example of an N-port custom calibration test set that has an integrated ECal module. The ECal characterization is done at the test ports. This kind of custom calibration test set allows multiport VNAs to be calibrated with a single test port connection.

There are two things to note with this type of multiport solution. First, it does not actually reduce or eliminate the required number of physical connections that need to be made using either a 2- or 4-port ECal. What it does reduce is the number of calibration button pushes on the VNA. Second, there is a tradeoff of calibration sensitivity or accuracy. As was discussed earlier, the effect of switch attenuation in a switch matrix test set will now also apply to a switched-based multiport ECal solution. Does this imply that calibrations may need to be done more frequently as compared to a calibration done with either a 2- or 4-port ECal? It depends on the parameters required by the DUT and the difficulty of its specifications. At frequencies above 10 GHz or products that require high performance, this may be more of a problem.

Figure 14. Multiport ECal-based switch boxes offer the convenience of a single connection calibration, but with potential tradeoffs in performance.
Multi-Site Techniques to Improve Throughput

Multi-site, or parallel measurements, describe the use of a single test station to test multiple devices at the same time (Figure 15). Simultaneous measurement of multiple devices, with the same test station, reduces the cost-of-test by increasing throughput while reducing capital expenses. The proliferation of wireless technologies is driving this need for very high-volume manufacturing of passive components, SAW devices for mobile handsets, as well as general-purpose components (e.g., antennas, filters, cables, etc.).

![Multi-site solutions reduce the cost-of-test by increasing throughput while reducing capital expenses.](image)

Multi-site testing may include multiple VNAs performing 2-port measurements, as well as any combinations of ports and VNAs. In the past multi-site may have meant stacking multiple ENA or PNA box instruments in a single rack. A new approach using independent PXI VNA modules can enable improved throughput and offer more flexibility than conventional solutions.

Unlike sequential measurements by a switch-based solution, the PXI VNA offers multi-site capability to measure multiple paths of the DUT simultaneously. For example, DUTs with two, four, or even more ports can be tested at the same time with PXI modules identified under a single PXI controller. It is possible to run simultaneous measurements of different devices or different measurement paths of a single multiport component with optimized stimulus setup (e.g., frequency, power level, IFBW or number of points, etc.) to increase overall measurement throughput for production testing. Figure 16 illustrates the multi-site measurement capability with the PXI VNA.

![The PXI VNA multi-site capability increases throughput, resulting in a significantly lower cost-of-test per device.](image)

It should also be noted that for this part of the discussion it does not matter whether the VNAs are 2-port or multiport. The only effect multiport would have is – do all of the required VNAs fit in a single chassis.
Considerations when configuring multi-site solutions

First let’s discuss some considerations when building a multi-site solution.

Controller / CPU

In a multi-site configuration, multiple instances of the VNA software are launched and each software instance is connected to either an individual or multiport VNA. Each instance behaves as an independent instrument to be used simultaneously and each VNA may be optimized with specific measurement conditions for each device under test, so you can balance speed and accuracy.

Embedded versus external controller

In a multi-site configuration, there is a single controller, which may be either an embedded controller or an external controller. The multi-site solution is unaffected by whether or not one uses an embedded or external PC controller; the measurement speeds and throughput will be comparable.

The bandwidth of the external PC is not an issue; the bottleneck will be the CPU. As the number of instances of independent VNAs increase, the controller has more computational work to accomplish, and at some point the processor performance will start to slow down. In these cases, the effect would be the same for either an embedded or external controller.

Number of cores versus VNAs

So what does affect measurement speed and throughput when there are multiple instances of PXI VNAs running simultaneously in a single PXI chassis?

Our latest testing on the controller processor speed and performance is that with the number of independent VNAs equal to the number of ‘cores’ in the processor, there is no noticeable degradation of processor speed in multi-site operation. Thus for a Keysight M9037A quad-core embedded controller, up to four independent VNA instances can be operated in one PXI chassis with no noticeable degradation in processing speed.

The VNA’s IF bandwidth (IFBW) setting does have a significant impact on the overall throughput of the measurement. For lower resolution bandwidths (such as 1 kHz), one can scale far beyond one core per VNA instance. However, at the faster IFBW of 100 kHz or greater, the one core per VNA instance argument holds.
Let’s look at an example that adds up to 16 2-port VNA modules to perform multi-site tests and see how well the system scales as modules are added. In this case we tested both a dual and quad core controller at IFBWs of 1 kHz and 100 kHz. Up to 16 modules were added in each of these four cases to see how many DUTs per second could be measured. Figures 17 through 20 show the results of this example.

Figure 17. Dual core, preset 300 kHz ≥ 26.5 GHz with 201 points at 1 kHz IFBW – this case does not use the CPU much because the IFBW is lower.

Figure 18. Dual core, preset 300 kHz ≥ 26.5 GHz with 201 points at 100 kHz IFBW – this case uses the CPU more heavily because the IFBW is high.

Figure 19. Quad core, preset 300 kHz ≥ 26.5 GHz with 201 points at 1 kHz IFBW – this case does not use the CPU much because the IFBW is lower.

Figure 20. Quad core, preset 300 kHz ≥ 26.5 GHz with 201 points at 100 kHz IFBW – this case uses the CPU more heavily because the IFBW is high.
Multi-site performance with the PXI VNA is heavily dependent on how intensive the CPU is used during the task. As expected, the results show that the quad core scales better than the dual core.

The actual measurement parameters required during production testing and their effect on the CPU is the most critical factor, with the IFBW settings dominating the overall throughput in this example. The 1-kHz setting scales well as the number of modules increases. At an IFBW of 100 kHz, the performance will instead scale with the number of CPU cores.

At the faster IFBW of 100 kHz, the results did not scale exactly as expected. For example, one PXI VNA with the quad core can measure 28 DUTs / second (DPS). Adding a second PXI VNA resulted in 52 DPS, and a third PXI VNA in 73 DPS. So, the efficiency was not perfect. In theory the three PXI VNAs should been able to measure 84 DPS. This may be due some overhead being required to allocate the processors in coordination among the multiple cores. This example highlights that results may vary depending on the actual VNA settings required for a specific application.

Future investigations could determine how these results would scale as the number of cores increases beyond the four used in this testing. At the higher IFBW values, results may see significant scalability gains by replacing the CPU with a higher performing one.

Backplane speed and memory

For multiport and multi-site PXI applications the PXI backplane speed limits will most likely never become a throughput issue. Let’s consider an example of a 16-port VNA using eight PXI VNA modules and an IFBW of 100 kHz.

An IFBW of 100 kHz translates to processing 100,000 points per second or 10 µsec per point. Multiply that by the number of receivers – 32 in the case of eight PXI VNA modules. Now there are 3.2 million buckets processing per second. Each bucket has a size of either 32 or 64 bits; let’s assume 64 bits or 8 bytes. This then becomes 25.6 million bits per second (25.6 MB/s). With the bandwidth of the external controller being 4 GB/s, it is clear that there is a lot of extra room.

It is also unlikely that RAM memory would become a limiting factor. Each instance uses very little «private» memory. For larger states, each instance may use 200 MB of private memory. For eight instances, that is using less than 2 GB of memory.

PXI chassis

With the PXI VNA requiring only one PXI slot, there is room for up to 16 PXI VNA modules in a single chassis. It is important to be sure to use the PXIe or Hybrid slots to achieve the full performance of the PXI VNA.
Multi-display/multi-user

While multi-site is often applied in highly automated environments, there are also cases where multi-site is desired for multi-operator testing. An example may include low cost filter tuning manufacturing. Figure 22 shows a four 4-port VNA multi-site configuration that provides a work station for four test operators. The limit on the number of test stations is dependent on available hardware and ports for both the PXI chassis and the computer peripherals.

There are some areas to watch out for that will be covered in the next sections.

![Diagram of multi-site capabilities](image)

Controller hardware

Figure 22 shows a multi-user configuration using the Keysight M9037A embedded controller. This controller has two display port outputs which may be routed directly to two of the monitors. Using the USB3 port, we route a path to an external USB3 hub. Two paths from the hub are routed to a USB3 to DVI video converter. These paths are then routed to the other two monitors. From this point, additional monitors can be added beyond the four shown in this example.

An alternative could be to use an external controller, perhaps a desktop computer with a more powerful video gaming board. This would allow more standard video connections without the need for USB3/video converters. Whether an embedded or external controller is used, it should be noted that this configuration will work best for VNA display information. Routing video intensive information, such as HD training videos, across all these displays may degrade performance. For VNA testing, this should not be an issue.

In this example, the USB3 hub is also being used to route the control signals for each of the touchscreen monitors or test station mice.
Microsoft Windows limitations

The computer operating system has to be configured to both support the multi-display capability and be able to recognize one test station from the other. These are standard Microsoft Windows capabilities.

First, the computer needs to be setup to recognize each of the monitors (Figure 23). Next, each of the monitors needs to be configured to be recognized as a particular test station (Figure 24). This should also include calibrating the pointing device – either the touchscreen or the mouse.

![Figure 23. Set up the computer to recognize each of the monitors.](image)

![Figure 24. Configure and calibrate each test station display to be recognized by the computer.](image)

Finally, and most important, there is a very common feature of Microsoft operating systems that needs to be recognized as a clear limitation of the multi-user capability. If two or more operators try to control the computer at the EXACT same time, errors may occur (Figure 25). As with most PCs, no two people can drive a single computer at the same time. Special consideration should be used to minimize the amount of operator control time in the multi-user environment.

![Figure 25. Standard Microsoft operating systems do not allow simultaneous user inputs.](image)
Minimizing operator control time with macros

One method of minimizing the need for operators to interface with the computer is to simplify and limit control access. One way to achieve this is by setting up graphical macros to cover any needed changes during testing (Figure 26). This minimizes the need for keyboard data entry and accessing drop down menus. Keeping all activity to simple pointing and clicking greatly reduces the likelihood of operators simultaneously trying to control the system.

Note that this sensitive timing issue is limited to the actual control time of the computer and is not a function of the test time of the VNA. Only during the fraction of a second that the operator accesses the macro button is there a concern.

Optimizing multiport testing with multi-site techniques

For multiport devices with high isolation, multi-site measurement techniques can further increase throughput by performing simultaneous sweeps on a multiport DUT (Figure 27). Examples of DUTs may include:

- Devices that have multiple independent switches inside a single component
- Front End Modules (FEM) where isolation tests are not necessary between high and low bands
- Interconnects such as cable assemblies with shielded differential lanes or connectors.

Figure 27 shows a 12-port device that is designed to have high isolation between ports 1-6 and ports 7-12. In this case, a true multiport test solution can test the entire device in just 12 sweeps. However, taking advantage of the PXI VNA modular capability and understanding the nature of a high isolation DUT will allow the test station to be reconfigured to be two 6-port VNAs in a multi-site configuration. This will allow the test station to reduce test time by an additional 50% by testing each of the six ports of the DUT simultaneously (Figure 28). Note that the two 6-port VNAs are independent and may simultaneously test at different frequencies.
Figure 28. Reconfiguring a 12-port VNA into two 6-port VNAs reduces test time by 50% by enabling simultaneous measurements on a high-isolation device.

Summary

Driving down the cost-of-test is the key challenge in high-volume component manufacturing. Keysight’s PXI VNA introduces many new capabilities that improve throughput while offering more flexible test configurations than conventional benchtop solutions. For multiport applications, the PXI VNA offers a true multiport capability that allows test engineers to configure up to a 32-port VNA in a single PXI chassis. In addition, it enables multi-site testing in a reconfigurable form factor that allows you to multiply your throughput in a single test station.

References

5. Handbook of Microwave Component Measurements with Advanced VNA Techniques, Joel Dunsmore, Ph.D., October 2012
AdvancedTCA® Extensions for Instrumentation and Test (AXIe) is an open standard that extends the AdvancedTCA for general purpose and semiconductor test. Keysight is a founding member of the AXIe consortium. ATCA®, AdvancedTCA®, and the ATCA logo are registered US trademarks of the PCI Industrial Computer Manufacturers Group.

LAN eXtensions for Instruments puts the power of Ethernet and the Web inside your test systems. Keysight is a founding member of the LXI consortium.

PCI eXtensions for Instrumentation (PXI) modular instrumentation delivers a rugged, PC-based high-performance measurement and automation system.