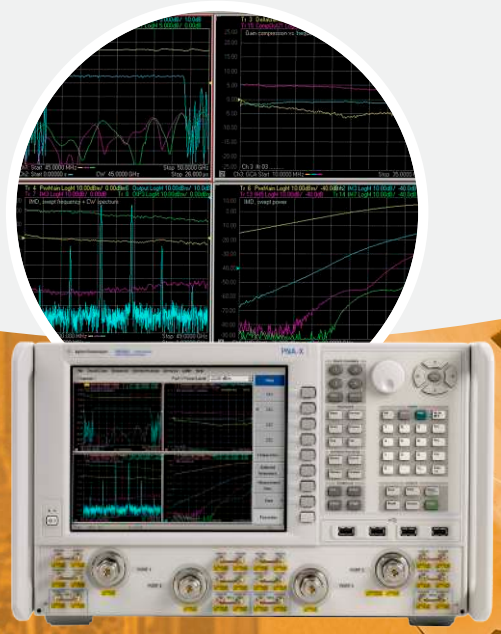
Solutions for

Transmit/Receive Module Test



Reach for unrivaled excellence in TR module testing

Anticipate ___Accelerate ___Achieve

Agilent Technologies

Technology trends and their impact on test

Radar, satellite and electronic warfare (EW) systems utilize a wide variety of microwave modules. For example, Active Electronically Steered Arrays (AESA) include thousands, or even tens of thousands, of Transmit/Receive (TR) modules. TR modules typically need extensive testing to ensure that they are matched across the phased array in which they are used. To complicate matters, many modules are smart devices that operate in a variety of modes and require multiple commands from the test platform for each test. In addition, each module is tested at multiple steps in the assembly process and traceability is required from step to step.

Across these applications, a common set of issues tends to occur during testing in the engineering and production environments. The overall cost of test is directly related to three major factors: the labor burden, the equipment cost, and the total test time accumulated across all steps in the process.

The Agilent PNA-X Series microwave network analyzers offers a high performance integrated solution for addressing the most challenging test needs of today's TR module. This brochure provides an overview of the PNA-X's unique benefits in meeting the test needs of the next generation of TR modules.

Market trends

Increasing frequencies, bandwidths, and resolutions

- Architectures support multiple functions
- More bands/shared spectrum/simultaneous operation

More sophisticated algorithms and signals

- Applying "Information Theory" to more applications
- Signals adapt to detected targets and conditions

Solid state enables more applications

- Higher performance (GaAs, GaN, SiC)
- Lower cost (SiGe & even CMOS at mmWave)
- MMIC, SoC, Radar-on-a-chip

Number of array elements increasing

- Element cost, size and power decreasing
- Higher levels of integration
- Must improve test throughput

Calibrating at the array level

- Module volumes drive new approaches to calibration and functional tests
- More expensive test facilities

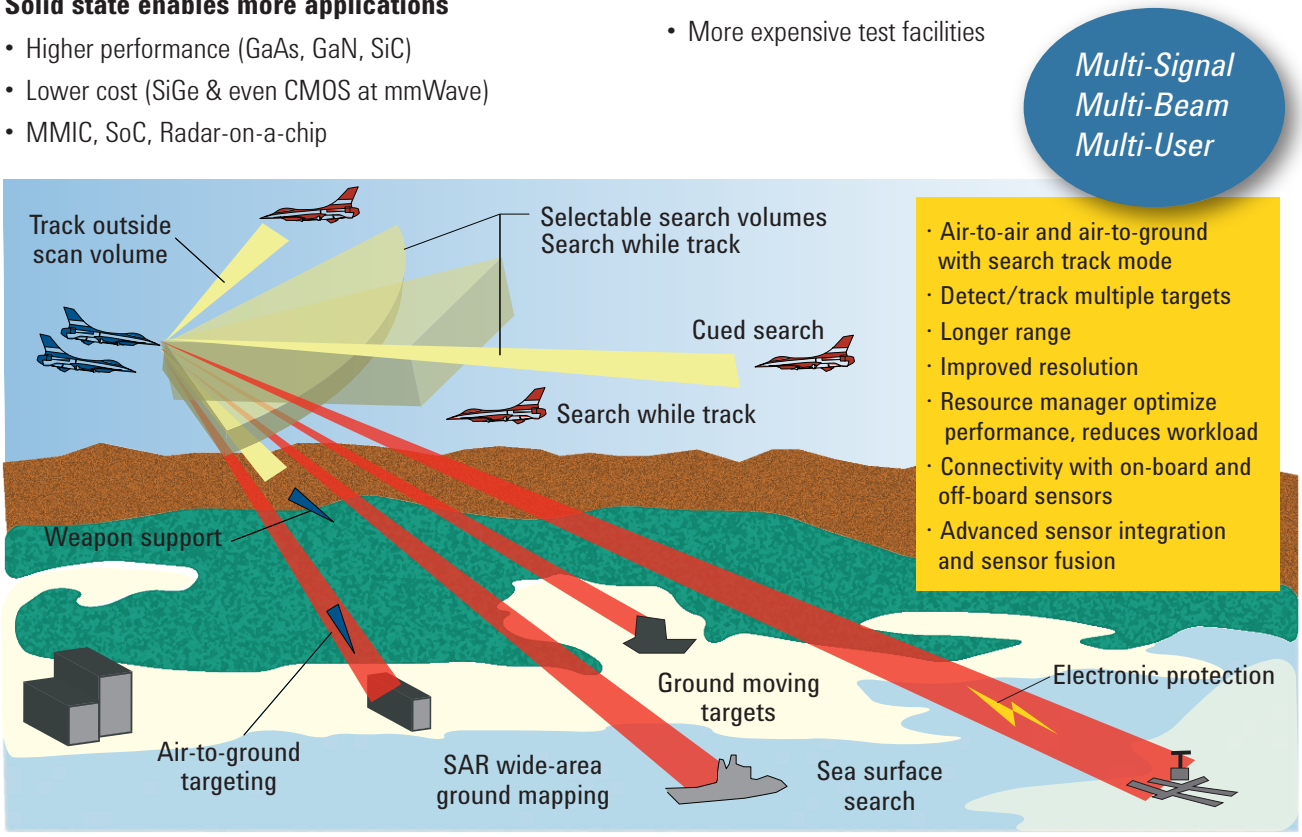
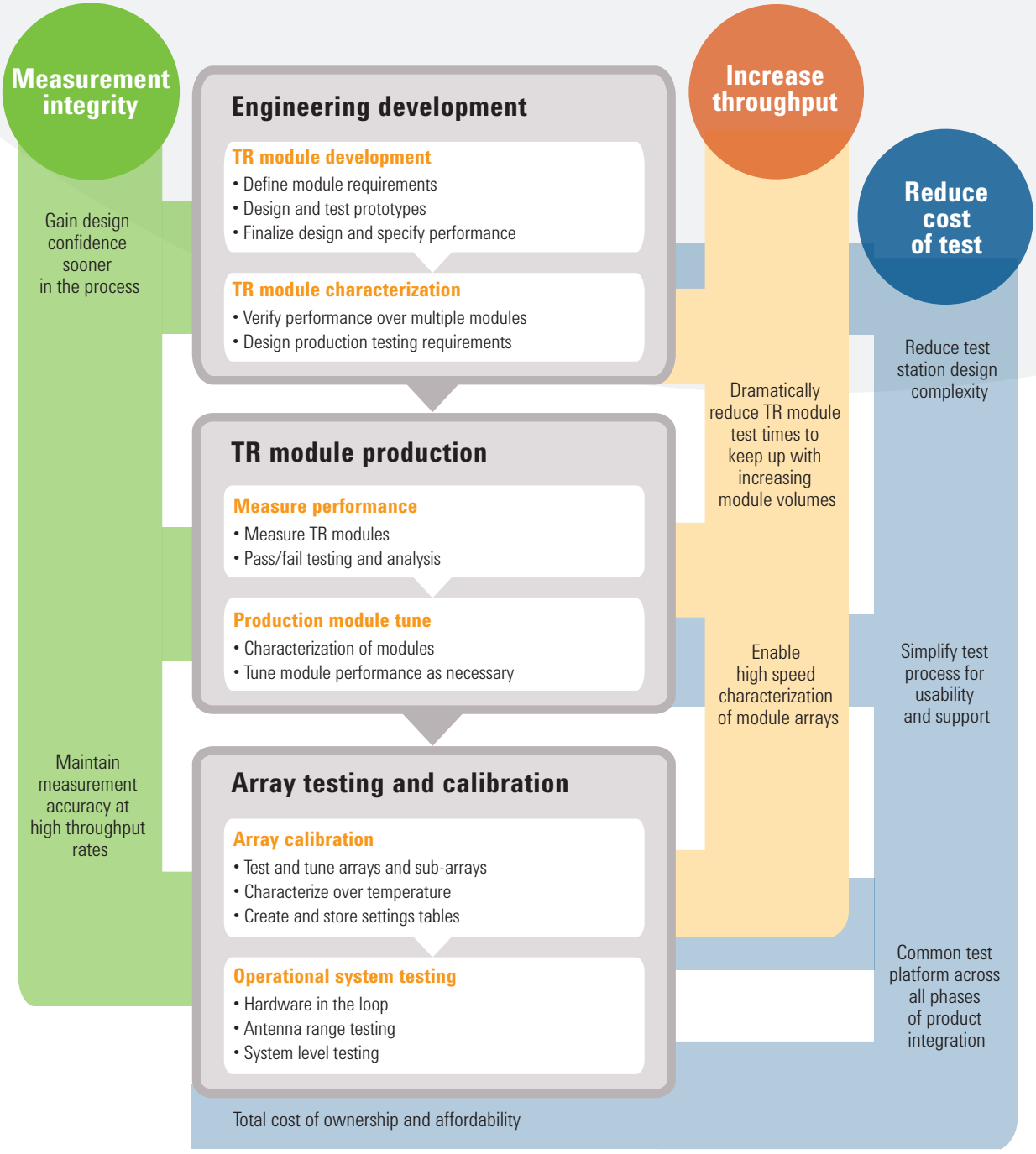


Figure 1. Multi-function designs with flexible and reactive interleaving of advanced modes increase TR module design complexity.

The goal: meet increasing volume demands with high quality TR modules

TR module testing challenges

- **Improve accuracy and repeatability over tighter specifications**
  The need to meet requirements of high performance TR modules
- **Dramatically increase your throughput to meet module volumes**
  New designs are requiring tens of thousands of modules that need to be tested at both the module and array level.
- **Ramp up your capabilities, but with tighter budgets**
  The need for a simplified test platform that can be used for all test needs



Measurement Integrity

Gain Deeper Confidence

TR modules have a major effect on RF performance. During transmit operations the output RF pulse is amplified by the module, thereby defining the maximum radiated power of the radar. Because the transmitter is operated in pulsed mode, output pulse parameters are typically measured. During receive operations the low-noise amplifier (LNA) within the module input determines the system noise figure and consequently the minimum detectable signal. Within each path, programmable phase shifters and attenuators control the antenna beam-steering and determine the angular accuracy of the radar.

The PNA-X's industry leading performance provides the measurement integrity you need to ensure accurate and repeatable test results across the wide range of testing required by today's advanced TR modules. The following highlights the unique measurement capabilities of the PNA-X.

Table 1. Typical TR Module Measurements

Module section	Key measurements

Receiver	• Gain and VSWR versus frequency
	• Noise figure versus frequency
	• Spectrum: harmonics, spurious and intermodulation
	• Attenuation and phase shift versus frequency
	  • Programmable (five to eight bits for each)
	  • 1,000 to 65,000 states per frequency

Transmitter	• Gain and VSWR versus frequency • Attenuation and phase shift versus frequency • Compression (maximum transmitter power versus frequency • Pulse profile: phase and amplitude, pulse width, rise and fall times • High power characterization over temperature • Spectrum: harmonics, spurious and intermodulation
Other	• Timing delays (programmable) • Current: peak and average • Module status

Pulsed-RF

Fast and accurate pulsed-RF measurements

- Full control of two internal pulse modulators and four internal independent pulse generators
- Point-in-pulse measurements with 20 ns min. pulse width
- Pulse profile measurements with 10 ns min. resolution
- Improved narrowband detection using hardware filters and patented spectral-nulling and software IF-gating techniques
- Wideband detection with pulse widths as narrow as 100 ns
- Receiver leveling improves the pulsed-RF power accuracy from ± 1 dB to less than 0.05 dB
- Pulse I/O connector on rear panel for external equipment and TR module synchronization

Noise Figure

Unique source-corrected noise figure solution

- Highest accuracy in the industry using advanced error-correction methods in automated-test environments
- Typically 4 to 10 times faster than Agilent's NFA Series noise figure analyzers
- Uses modified cold-source method, eliminating need for noise source when measuring TR modules

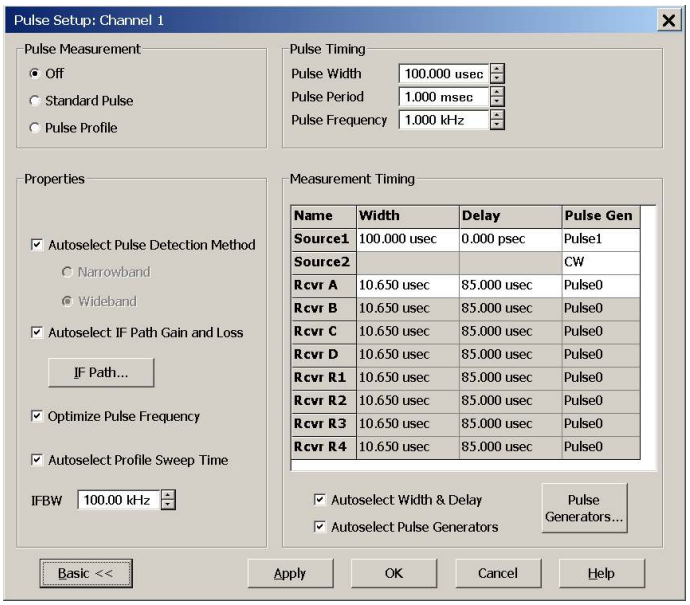


Figure 2. The PNA-X automatically optimizes internal hardware for specified pulse conditions to dramatically simplify test setups.

Maintain Measurement Accuracy

Measurement Integrity

Gain Compression

Gain compression versus frequency measurements

- Guided calibration provides power and mismatch correction
- Complete device characterization with two-dimensional sweeps
- Flexibility with a variety of compression methods—compression from linear gain, maximum gain, X/Y compression, compression from back-off, or compression from saturation

Intermodulation Distortion (IMD)

Two-tone intermodulation distortion (IMD) measurements

- Fast swept measurements using internal combiner and two internal sources
- Spectrum analyzer mode for troubleshooting or making spurious measurements, eliminating the need for a separate spectrum analyzer
- Very clean internal sources and wide receiver dynamic range, minimizing measurement errors caused by other instruments

Module Array Testing

Fast and accurate RF subsystem for array module measurements

- 400,000 data points per second simultaneously on five receivers, yielding three to five times improvement in test times compared to the Agilent 8530A
- Large data collections with 500 million point circular First IN First OUT (FIFO) data buffer
- Excellent measurement sensitivity via selectable IF bandwidths and point averaging mode

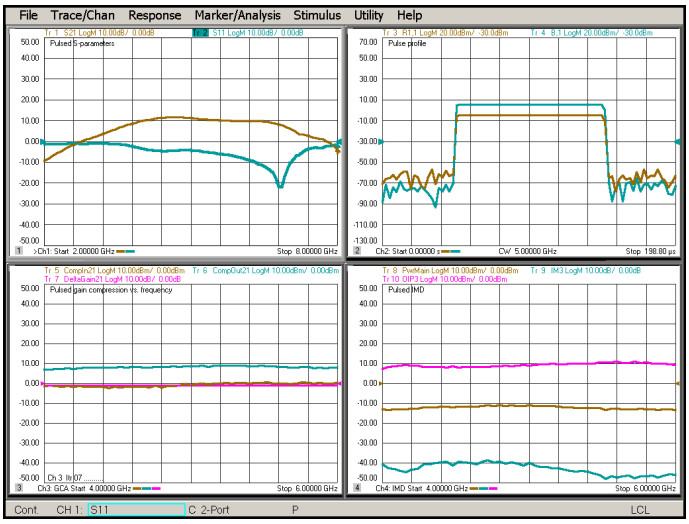


Figure 3. The PNA-X accurately characterizes active devices under pulsed operation with a single set of connections to the TR module - pulsed S-parameters, pulse profile (input and output power in the time domain), gain compression versus frequency, and swept frequency IMD are measured in this example.

Figure 4. Measures third order IMD and IP3 at 201 frequency (or power) points in a matter of seconds, compared to several minutes using signal generators and a spectrum analyzer.

Increase Throughput

Optimizing Your Test Sequence for Speed

When a phased array includes thousands of TR modules, test throughput becomes a critical requirement. TR modules typically need extensive testing to ensure that they all match across the phased array. To complicate matters, many modules operate in a variety of modes which require multiple commands for each test. In addition, each module is tested at multiple steps in the assembly process and traceability is required from step-to-step.

The most time-consuming measurements involve the characterization of the attenuator and phase-shifter responses. These are typically interactive because the attenuator affects the phase shifter and vice versa. For comparison purposes, assume a TR module with a six-bit phase shifter and a six-bit attenuator, each can have between 32 and 256 possible states, resulting in 4096 possible permutations. Because these states are frequency-dependent, they are typically measured at multiple frequencies. Typically it is much faster to change the TR module states than to change frequencies on the VNA.

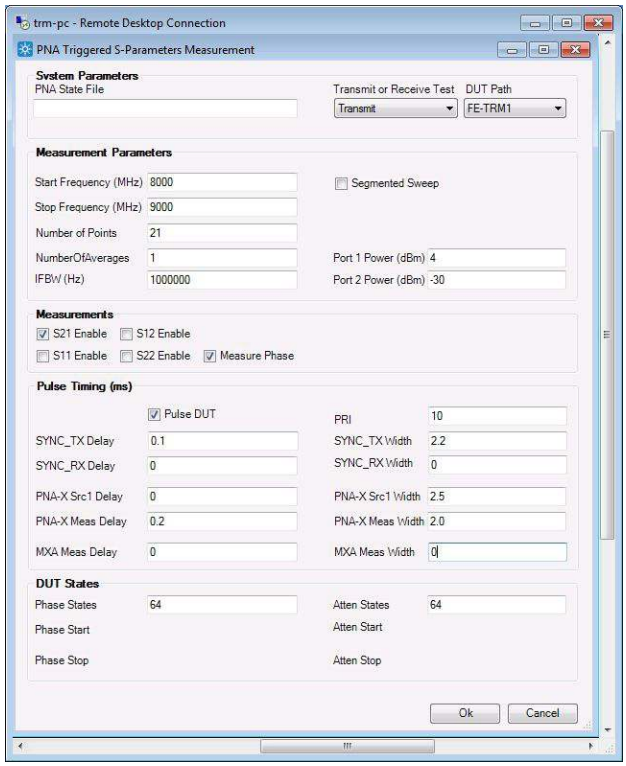
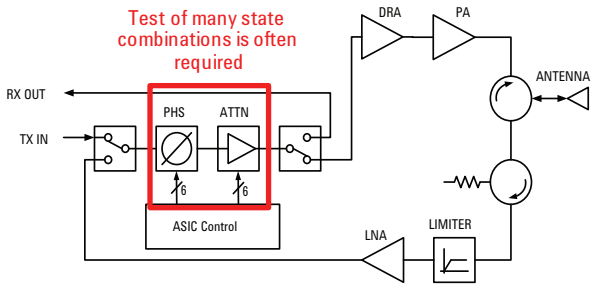


Figure 5. Tight integration of the PNA-X and the TR module is required in order to optimize the overall test sequencing.

Optimize Test Sequences Across Thousands of TR Module States



Example Test Sequence

1. Fix all test parameters
2. Configure PNA-X in Fast CW mode
   - Collect 400,000 data points/second on five measurement channels simultaneously
   - 500 million point circular first-in-first-out (FIFO) data buffer
3. Collect measurements while stepping through all required combinations of phase shifter/attenuator settings
4. Change PNA-X test parameter (e.g. frequency)
5. Repeat #3-4 as required

Optimizing software control of the PNA-X and TR module

- Test algorithms that make optimum use of the PNA-X's capabilities
- Hardware-controlled TR module and instrument management that eliminates software latency
- Very low measurement overhead in calling test algorithms and managing data
- Overlapped I/O with new measurements being made while the previous data is being retrieved

TALK TO AN EXPERT

Contact your local Agilent sales office for system integration and programming assistance.

Accelerating Throughput Eliminates the Need for Legacy Tradeoffs

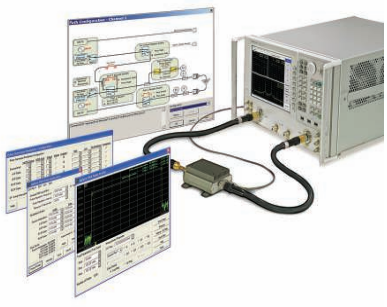
Increase Throughput

During the development process, the engineering team performs a very wide range of measurements. With a typical legacy test platform, it could take more than 60 hours to perform such an extensive set of measurements.

Clearly, 60-hour test times were not feasible in production and in reality were an obstacle in engineering too. The simplest way to achieve a shorter test time is to reduce the number of measurements, especially for phase and attenuation.

The PNA-X is designed to be controlled for automated applications that enable test solutions to be optimized for throughput. The example test platform data shown can perform complete characterization of a TR module with 700,000-plus measurements requiring an average test time of less than 5 minutes. Depending on the mix of measurements, the PNA-X based test platform can perform an order of magnitude more measurements in less than one-tenth the time required by the previous legacy test systems. As a result, the overall speed improvement is approximately two orders of magnitude

By the 1990s, the HP 8510 was the industry standard for pulsed-RF vector network analyzers.



Providing the first one-box pulsed-RF test system, the PNA-X sets a new standard for simplicity, speed, and accuracy

Table 2. The reduction of measurements to reduce test time on the legacy TR system is no longer required with the PNA-X

		Legacy T/R Test System						PNA-X T/R Test System		
		Ideal requirement			Reduced for production			Ideal requirement		
Measurement	**Chan**	**Pts**	**Freqs**	**Total**	**Pts**	**Freqs**	**Total**	**Pts**	**Freqs**	**Total**
RCVR gain and VSWR	4	2	201	1608	2	201	1608	2	201	1608
RCVR noise figure	**4**	**1**	**11**	**44**	**1**	**3**	**12**	**1**	**11**	**44**
RCVR phase and attenuation	**4**	**4096**	**21**	**344064**	**128**	**21**	**10752**	**4096**	**21**	**344064**
RCVR spectrum	4	2048	1	8192	2048	1	8192	2048	1	8192
XMTR gain and VSWR	4	2	201	1608	2	201	1608	2	201	1608
XMTR phase and attenuation	**4**	**4096**	**21**	**344064**	**128**	**21**	**10752**	**4096**	**21**	**344064**
XMTR compression	**4**	**1**	**201**	**804**	**1**	**3**	**12**	**1**	**201**	**804**
XMTR pulse profile	4	20	1	80	20	1	80	20	1	80
Timing	4	24	1	96	24	1	96	24	1	96
Supply current	4	3	1	12	3	1	12	3	1	12
Module status	1	1	1	1	1	1	1	1	1	1
Total measurements				**700,573**			**33,125**			**700,573**
Approximate test time				60 hrs			30 min			5 min

Reduce Cost of Test

Common Test Platform Across All Phases of Product Integration

Benefits for Engineering

Using the PNA-X to achieve extremely high throughput opens new capabilities to users in both production and engineering. For engineering, very high-speed testing makes it possible to measure all module modes and parameters with fine resolution (useful when looking for anomalies) in a few seconds. Engineers need not make compromises between fast turnaround and the quantity of data gathered. One positive consequence: this encourages more thorough testing of extreme conditions (e.g., temperature, shock and environmental) because the electrical parameters can be measured quickly relative to variations in those conditions. The large quantities of data gathered can also be used to improve component modeling.

Benefits for Production

For production, the most important improvement is a dramatic reduction in test time. The ability to maintain the traceability of test results from engineering through each step in production has multiple benefits: it helps ensure delivery of a quality product, and it improves the production process by helping determine the sources of parameter variations. In addition, comprehensive testing reduces the risk of shipping a module with one or more anomalies. It also has the potential to improve yield through the use of narrower tolerance bands because all data points are measured. As a final benefit, comprehensive testing enables sorting and matching of modules to meet special needs, potentially at a premium price.

Managing the Total Cost of Ownership

Cost of ownership is always a hot topic when making a program decision for any new upgrade or sustainment option. The Total Cost of Ownership (TCO) is defined to be the total cost to own and operate a piece of equipment over its useful life. TCO shows how operating costs can be critical drivers in reducing total costs beyond simply lowering acquisition (capital) costs. Agilent PNA-X based test solutions offer the lowest cost of ownership with:

- 3 year warranty standard on all products, with options up to 5 years
- 12 month calibration intervals
- Code compatibility offering the option to re-use existing test code
- Test equipment that holds its value longer than any other test and measurement company

Figure 6. Agilent PNA-X based test solutions offer the lowest cost of ownership in the test and measurement industry.

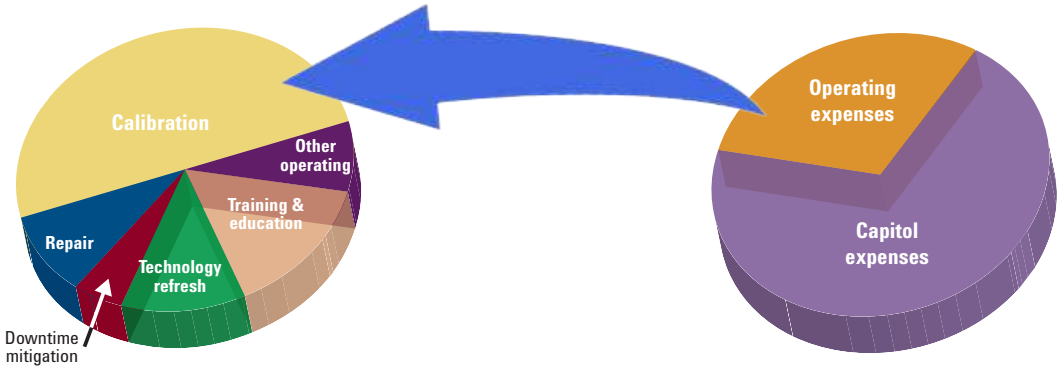


Figure 7. Calibration of the equipment (i.e. metrology) is usually the largest cost component of preventive maintenance expenses. In this regard, calibration cycle period is the single largest lever to pull on to reduce such metrology costs.

Reduce Test Station Design Complexity

Reduce Cost of Test

Multiple Measurements With a Single Instrument

With its highly integrated and versatile hardware and re-configurable measurement paths, the PNA-X replaces racks and stacks of equipment – with a single instrument. One PNA-X can take the place of the following test gear:

- Network analyzer
- Spectrum analyzer
- Two signal sources
- Noise figure meter/analyzer
- Power meters
- Switch matrix
- Digital voltmeter

Benefits of a PNA-X-Based Solution

• Simpler test systems for...
...lower hardware and software costs
...quicker development time and faster time to manufacturing
...less downtime and lower maintenance costs
...smaller size and lower power consumption

• Faster test times for...
...improved throughput

• Higher accuracy for...
...smaller error margins and less rework
...better yields and better specifications
...improved profit margins from tighter characterization

• Flexible hardware for...
...both bench-top development and automated production test
...greater adaptability to future test requirements

Figure 8. The PNA-X with IMD application replaces two signal generators and a spectrum analyzer in the system rack, simplifying the system configuration and increasing test throughput

PNA-X - The Industry's Most Advanced RF Test Solution

The PNA-X Series of microwave network analyzers are the culmination of Agilent's 40-year legacy of technical leadership and innovation in radio frequency (RF) network analysis. More than just a vector network analyzer, the PNA-X is the world's most integrated and flexible microwave test engine for measuring TR modules. The combination of two internal signal sources, a signal combiner, S-parameter and noise receivers, pulse modulators and generators, and a flexible set of switches and RF access points provide a powerful hardware core for a broad range of linear and nonlinear measurements, all with a single set of connections to your TR module.

In addition to the previously mentioned capabilities the PNA-X's unique hardware architecture also offers:

- Frequency converter capability provides input and output match, conversion loss/gain, compression, IMD and noise figure measurements of phase and absolute group delay
- Mixed-mode S-parameters for differential devices may be driven by true differential and common-mode signals
- Fully integrated solution for millimeter-wave pulse measurements using built-in pulse modulators, pulse generators, and receiver gates
- X-parameters* to characterize nonlinear device behavior using measurement-based data

Complete linear and nonlinear component characterization in a single instrument

Single Connection With Calibration Refresh Modules

Agilent Technologies 855xxA/B Series calibration refresh modules, also known as CalPods, provide a new and unique way to quickly and easily refresh a network analyzer calibration. With calibration refresh modules, you can be assured of a valid calibration quickly – at the simple touch of a button, without removing the TR module, and without the physical connection of standards.

- Provide the closest device tolerances in production testing
- Very accurate phase measurements
- Remove switch matrix repeatability errors
- Remove switch and connector repeatability errors in complex ATE test systems
- Temperature chamber testing
- Measurement of low-loss devices
- Applications that require frequent recalibrations
- Applications that have complex and lengthy calibrations, such as multi-port measurements

Figure 9. CalPod calibration refresh modules are in-situ devices that can remove the effects of environmental variations in test cables, connectors, adaptors, switch matrices, to re-establish a valid calibration at the measurement plane.

*X-parameters is a registered trademark of Agilent Technologies. The X-parameter format and underlying equations are open and documented. For more information, visit http://www.agilent.com/find/eesof-x-parameters-info

PNA-X Network Analyzer and Option Configuration Information

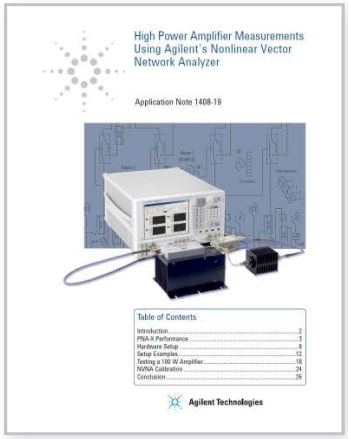
To add options to a product, order the corresponding item number.

	Description	N5249A 10 MHz to 8.5 GHz	N5241A 10 MHz to 13.5 GHz	N5242A 10 MHz to 26.5 GHz	N5244A 10 MHz to 43.5 GHz	N5245A 10 MHz to 50 GHz	N5247A 10 MHz to 67 GHz	Additional information
Test set								
Option 200	2-ports, single source	N5249A-200	N5241A-200	N5242A-200	N5244A-200	N5245A-200	N5247A-200	
Option 224	2-ports, add internal 2nd source, combiner and mechanical switches	N5249A-224	N5241A-224	N5242A-224	N5244A-224	N5245A-224	N5247A-224	Requires Options 200, one of 219 or H85, and 080
Option 400	4-ports, dual source	N5249A-400	N5241A-400	N5242A-400	N5244A-400	N5245A-400	N5247A-400	Option 080 recommended
Option 423	4-ports, add internal combiner and mechanical switches	N5249A-423	N5241A-423	N5242A-423	N5244A-423	N5245A-423	N5247A-423	Requires Options 400, one of 419 or H85, and 080
Power configuration								
Option 219	2-ports, extended powerrange and bias-tees	N5249A-219	N5241A-219	N5242A-219	N5244A-219	N5245A-219	N5247A-219	
Option 419	4-ports, extended power range and bias-tees	N5249A-419	N5241A-419	N5242A-419	N5241A-419	N5242A-419	N5247A-419	
Measurement applications								
Option 010	Time-domain measurements	N5249A-010	N5241A-010	N5242A-010	N5244A-010	N5245A-010	N5247A-010	
Option 029[2]	Fully-corrected noise figure measurements	N5249A-029	N5241A-029	N5242A-029	N/A	N/A	N/A	Requires one of Options 219, 224, 419, 423, or H85, and for measuring frequency converters, requires Option 082 or 083
Option 080	Frequency offset	N5249A-080	N5241A-080	N5242A-080	N5244A-080	N5245A-080	N5247A-080	
Option 086	Gain compression application	N5249A-086	N5241A-086	N5242A-086	N5244A-086	N5245A-086	N5247A-086	Recommend Options 219, 419 or H85 and for measuring frequency converters, requires Option 082 or 083
Option 087	Intermodulation distortion application	N5249A-087	N5241A-087	N5242A-087	N5244A-087	N5245A-087	N5247A-087	Requires Options 224 or 423 and for measuring frequency converters, requires Option 082 or 083
Pulse, antenna, mm-wave								
Option 008	Pulsed-RF measurements	N5249A-008	N5241A-008	N5242A-008	N5244A-008	N5245A-008	N5247A-008	Requires Option 025
Option 020	Add IF inputs for antenna and mm-wave	N5249A-020	N5241A-020	N5242A-020	N5244A-020	N5245A-020	N5247A-020	
Option 021	Add pulse modulator to internal 1st source	N5249A-021	N5241A-021	N5242A-021	N5244A-021	N5245A-021	N5247A-021	
Option 022	Add pulse modulator tointernal 2nd source	N5249A-022	N5241A-022	N5242A-022	N5244A-022	N5245A-022	N5247A-022	Requires Option 224 or 400
Option 025	Add four internal pulsegenerators	N5249A-025	N5241A-025	N5242A-025	N5244A-025	N5245A-025	N5247A-025	
Option 118	Fast CW sweep	N5249A-118	N5241A-118	N5242A-118	N5244A-118	N5245A-118	N5247A-118	

Additional Information

Download the latest PNA-X application notes:

Bookmark this page to download the latest PNA-X application notes to gain in-depth measurement knowledge.



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