S-Parameter Passive & Active Device Characterization

Choose the Best Network Analyzer for Your Application

Giovanni D’Amore  Michael Benzinger  John Swanstrom
<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>8410A</td>
<td></td>
</tr>
<tr>
<td>1975</td>
<td>8542A Automation</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>8510A</td>
<td>set the industry standard</td>
</tr>
<tr>
<td>1986</td>
<td>8753 Series</td>
<td>New economy entry into RF market</td>
</tr>
<tr>
<td>1988</td>
<td>8720 Series</td>
<td>New economy entry into the Microwave</td>
</tr>
<tr>
<td>1991</td>
<td>8711 Series</td>
<td>Low Frequency</td>
</tr>
<tr>
<td>1996</td>
<td>8510XF</td>
<td>Single sweep up 110GHz</td>
</tr>
<tr>
<td>2000</td>
<td>PNA</td>
<td>New standard of performance</td>
</tr>
<tr>
<td>2001</td>
<td>ENA</td>
<td></td>
</tr>
<tr>
<td>2007-2010</td>
<td>PNA-X/NVNA</td>
<td></td>
</tr>
</tbody>
</table>
Agilent Vector Network Analyzer Portfolio

Test Accessories

Industry’s Broadest Price/Performance Choices

PNA-X, NVNA
Most advanced and flexible

PNA
High performance microwave

PNA-L
Economy microwave

ENA
High performance RF

ENA-L
Economy RF

Mm-Wave
Up to THz

PNA-X Receiver
Antenna measurements

FieldFox
Portable RF/MW Analyzer

... plus measurement applications!

Agilent Technologies
The Need for Component Test

• Components are underlying **building blocks** of RF systems

• Magnitude and phase information crucial for **simulation** during design stage

• Ensure devices meet **specifications** during manufacturing

### Monolithic Amplifiers: Surface Mount DC to 8000 MHz

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Frequency Range (MHz)</th>
<th>Gain (dB) Typ.</th>
<th>Max. Power Output @ 1 dB comp. (dBm) Typ.</th>
<th>N.F. (dB) Typ.</th>
<th>IP3 (dBm) Typ.</th>
<th>VSWR (@1) Typ.</th>
<th>Device DC Operating Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERA-1A</td>
<td>DC 8000</td>
<td>10.0</td>
<td>12.0</td>
<td>4.3</td>
<td>20.0</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>ERA-2L</td>
<td>DC 6000</td>
<td>14.4</td>
<td>13.0</td>
<td>4.0</td>
<td>25.0</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>ERA-3L</td>
<td>DC 3000</td>
<td>16.8</td>
<td>13.5</td>
<td>3.5</td>
<td>25.0</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>ERA-4L</td>
<td>DC 4000</td>
<td>13.4</td>
<td>17.3</td>
<td>4.1</td>
<td>34.0</td>
<td>1.1</td>
<td>1.3</td>
</tr>
<tr>
<td>ERA-5L</td>
<td>DC 4000</td>
<td>18.5</td>
<td>18.4</td>
<td>4.3</td>
<td>32.5</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>ERA-6L</td>
<td>DC 4000</td>
<td>12.2</td>
<td>17.0</td>
<td>4.5</td>
<td>30.0</td>
<td>1.3</td>
<td>1.6</td>
</tr>
</tbody>
</table>

(+ symbol indicates this Model is available as RoHS Compliant/Pb Free.)
S-parameters: Core of Linear Characterization at RF

- S-parameters: complex (magnitude and phase) **reflection** and **transmission** in forward and reverse directions
- Fully describe **linear** behavior of RF components
- Characterize **linear distortion** caused by non-flat amplitude and deviation from linear phase or constant group delay
- Necessary, but not sufficient for full system simulation
Non-Linear Distortion of Active Devices

- System impairments also result from **nonlinear** device behavior
- Important to include nonlinear characteristics in **simulation**
- Nonlinearities usually dependent on **power** presented to device
- Common measurements include gain **compression**, AM-to-PM conversion, and **harmonic** and **intermodulation** distortion
Vector network analyzers:
• Are stimulus-response test systems
• Can sweep frequency or power
• Characterize linear (S-parameters), and in the past, some nonlinear (e.g. compression) performance
• Are very fast for swept measurements
• Provide the highest level of measurement accuracy
VNA Basic Block Diagram
Traditional Vector Network Analyzer (Limitations)

- Single synthesized, sweeping source
  - Low power
  - High harmonic & spurious content

- Single non-synthesized LO
  - Phase-locked to RF source
  - No independently tunable receivers

- Harmonic samplers
  - High noise floor
  - Fixed, narrow IF bandwidths
  - No pulsed-RF capability

- Limited absolute calibration (power, phase)

- Only two ports typically

~ Year 1985
PNA-X (2-port) Test Set

~ Year 2000
4-Port 13.5/26.5 GHz PNA-X Options 419, 423, 029

Noise source used for calibration only

---

Impedance tuner for noise figure measurements

---

Rear panel

+28V

-
Product Features – Signal Sources

Second internal source

- Two-tone intermodulation tests (and more)
- LO signal for testing mixers/converters
  - About 30x faster than PNA/PSG combination
  - About 100x faster than PSA/PSG combination

Source improvements

- New upper frequency (26.5 GHz)
- High port power (~ +16 dBm)
- Low harmonics (> -60 dBc)
  - Improves accuracy for harmonic and IMD tests
  - Eliminates or reduces need for external filters
- Wide ALC range (40 dB)
  - Easily sweep power from linear to compression region
  - Increased flexibility for optimizing power for two-source tests
**Product Features – Test Set**

**Flexible signal routing**

- **Internal signal combiner**
  - Use for IMD, Hot S22, phase versus drive measurements
  - Easily switch between one and two source measurements

- **Front panel jumpers** to access couplers and receivers
  - Add high-power components for power amplifier measurements
  - Add reference mixer for mixer/converter measurements

- **Rear-panel signal routing** with mechanical switches
  - Add signal-conditioning hardware like filters, amplifiers
  - Add other test equipment to extend suite of measurements
Today's PNA's: More Complete Characterization of Components

- **Legacy PNA (E836xC)**
  - Scalar mixer cal
  - Vector mixer cal
  - Mixer with embedded LO

- **New PNA (N522xA)**
  - Gain compression
  - IMD/spectrum
  - Pulsed-RF

- **NVNA/X-Parameter**
  - Active load-pull/phase control
  - True-mode

- **PNA-X (N524xA)**
  - Single-connection multiple-measurements
  - Noise figure
  - Low-noise receiver for NF

---

Mixer with embedded LO

---

Analog Technologies
Replace **RACKs** and **STACKs**...

- **Save time, money, size, repair costs, downtime**
- **Improve accuracy, yield, margins**

... with the PNA-X!

- **VNA plus...**
  - Two sources with internal combiner
  - Power meter
  - Vector noise figure
  - Pulse modulators/generators
  - CW spectrum analyzer
  - DC inputs
  - Non-linear analysis

Last update: Nov 2010
Change Multi-Station Process to Single Instrument

Gain, match, isolation

Pulsed-RF

IMD, spurs, harmonics, noise figure

Old way: multiple test stations needed to complete required tests

New way: one instrument does it all!
PNA-X Revolution and Evolution…

For active-device characterization and tests
- Two and four ports, 10 MHz to 26.5 GHz
- Internal second source and signal combiner
- Unrivaled flexibility and configurability
- Internal pulse generators and modulators
- Very low source harmonics
- High receiver compression point

World’s most accurate noise figure measurements

Embedded-LO converter measurements

Gain compression application

Integrated true-mode stimulus

Intermodulation distortion application

PNA-X antenna measurement receiver

Breakthrough nonlinear vector network analyzer

Expanded frequency coverage: 13.5, 43.5, 50 GHz

Expanded frequency coverage: 67, 110 GHz

Feb 2007

2008

2009

2010
Leverage Your Investment to a Wide Range of Applications

- **Amplifier Test**: Single Connection: Gain compression, IMD, noise figure, harmonics, true differential, PAE, hot $S_{22}$
- **Antenna Test**
- **T/R Module Test**
- **Pulsed RF and DC**
- **Mm-wave**

**Materials Measurements**

**Mixer Test**

**NVNA**
Component characterization
X-parameter extraction
Pulse envelope domain

**Load pull**
Noise parameters

**www.agilent.com/find/pnax**

**Signals and Measurements**

**Pulsed RF and DC**

- **Spectrum Analyzer**
- **Scanning Microwave Microscope**

**110 GHz**

- **67 GHz**
- **50 GHz**
- **43.5 GHz**
- **PNA-X**
- **26.5 GHz**
- **13.5 GHz**

**13.5 GHz**

**26.5 GHz**

**43.5 GHz**

**50 GHz**

**67 GHz**

**110 GHz**

**Agilent Technologies**
PNA-X Offers Premier Network Analysis Performance

Agilent’s PNA-X Series network analyzers offer the highest performance, plus:

- **2- and 4-port** versions
- Built-in **second source** and **internal combiner** for fast, convenient measurement setups
- Unrivaled **flexibility** and **configurability**
- **Internal modulators** and **pulse generators** for fast, simplified pulse measurements
- High accuracy **noise figure** measurements using Agilent’s unique source-correction method
- Many **software applications**
- Large **touch-screen display** with intuitive user interface
2-Port 13.5/26.5 GHz PNA-X Options 219, 224, 029

Noise source used for calibration only

Impedance tuner for noise figure measurements

Test port 1

Source 1

Pulse modulator

OUT 1

R1

+28V

Test port 2

Source 2

Pulse modulator

OUT 1

OUT 2

Source 2

Source 2 Output 1

Source 2 Output 2

To receivers

LO

Mechanical switch

RF jumpers

receiver

IF inputs

rear panel

Noise receivers

10 MHz - 3 GHz

3 - 13.5/26.5 GHz

+35 dB

-65 dB

+35 dB

-65 dB

+35 dB

-65 dB

+35 dB

-65 dB

+35 dB

-65 dB

+35 dB

-65 dB
4-Port 13.5/26.5 GHz PNA-X Options 419, 423

![Diagram of 4-Port PNA-X Options 419, 423](image)

**Test ports:**
- **Test port 1:** R1
- **Test port 2:** R2
- **Test port 3:** R3
- **Test port 4:** R4

**Sources:**
- **Source 1 (standard):** OUT 1, OUT 2
- **Source 2:** OUT 1, OUT 2

**Pulse generators:**
- 1, 2, 3, 4

**Receive ports:**
- **R1:** 65 dB
- **R2:** 65 dB
- **R3:** 35 dB
- **R4:** 35 dB

**Mechanical switch:**
- J1, J2, J3, J4, J5, J6, J7, J8, J9, J10, J11

**RF jumpers:**
- Arrows indicating RF jumpers

**IF inputs:**
- J1, J2, J3, J4

**LO:**
- Arrows for LO signal

**Pulse modulators:**
- Arrows indicating pulse modulation

**Agilent Technologies**

*PNA-X Customer Presentation*

*Last update: Nov 2010*
4-Port 13.5/26.5 GHz PNA-X Options 419, 423, 029

Noise source used for calibration only

Source 1

Source 2

Pulse generators

Pulse modulator

Signal combiner

Test port 1

Test port 2

Test port 3

Test port 4

Noise receivers

10 MHz - 3 GHz

3 – 13.5/26.5 GHz

Impedance tuner for noise figure measurements

Mechanical switch

 RF jumpers

Receiver

Agilent Technologies
4-Port 43.5/50 GHz PNA-X Options 419, 423

Rear panel

Source 1
- OUT 1
- OUT 2
- Pulse modulator
- 60 dB
- 35 dB

Source 2 (standard)
- OUT 1
- OUT 2
- Pulse modulator
- 60 dB
- 35 dB

RF jumpers

Signal combiner

LO
- To receivers

Pulse generators
- 1
- 2
- 3
- 4

Test port 1
- R1
- 60 dB

Test port 3
- R3
- A
- 35 dB

Test port 4
- R4
- C
- 35 dB

Test port 2
- R2
- D
- 35 dB

IF inputs

Receiver

Mechanical switch

Agilent Technologies

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4-Port 43.5/50 GHz PNA-X Options 419, 423, H29

Noise source used for calibration only

Rear panel
+28V

Source 1

OUT 1
Pulse modulator

Source 2

OUT 1
Pulse modulator

RF LO
OUT OUT

Pulse generators

1 2 3 4
To receivers

LO

Noise receivers

10 MHz - 3 GHz
3 – 26.5 GHz

Signal combiner

Test port 1

R1

R3

C

R4

RF OUT
LO OUT

Test port 2

J9

J10

J8

J7

J6

J5

J4

J3

IF inputs

R A B C D

J2

J1

Test port 3

Test port 4

Impedance tuner for noise figure measurements

60 dB

35 dB

60 dB

35 dB

60 dB

35 dB

60 dB

35 dB

60 dB

35 dB

Mechanical switch

Receiver

RF jumpers
4-Port 67 GHz PNA-X Options 419, 423

- Port 67 GHz PNA
- Options 419, 423

Test port 1
Test port 3
Test port 4
Test port 2

Source 1
Source 2 (standard)

Signal combiner

RF jumpers
Receiver
Mechanical switch

To receivers

Pulse generators

Last update: Nov 2010
Rear Access Loops and Internal Switches

Add signal-conditioning hardware

**Example 1:**
Switch between normal path and high-power path
Extending Test Suite With Other Instruments

Example 2:
Switch between network analyzer and external source/ analyzer combination for ACPR testing with digital modulation

Spectrum analyzer

Signal generator

Network analyzer

To rear access loops

DUT
Single Connection, Multiple Measurements

Easily switch between measurements:

One signal source
- CW S-parameters
- Pulsed S-parameters
- Gain compression
- AM-to-PM conversion
- Harmonics
- Noise figure

Two signal sources
- Intermodulation distortion
- Hot-$S_{22}$
- Phase versus drive
- True-mode stimulus
- Conversion loss/gain
Single Connection, Multiple Measurements Example

5 channel setup with full calibration. No need to connect or disconnect between measurements. S-parameters + pulse profile + IMD + gain compression + noise figure. **Total time: 5.1s**

Previous ATE system took >186 s with less accuracy. **PNA-X result: more accurate and ~ 37x faster**

Ch1: Standard S-parameters. 201 pts, 2-port cal, 1 kHz IFBW. **500 ms**
Ch6: Pulse profile (S21), 401 pts, 2-port cal, using internal pulse gens/mods, 5 MHz IFBW. **33ms**

Ch2: Two-tone IMD using internal broadband combiner and two internal sources. 101 pts, src/rcvr cal, 100 Hz IFBW. **950ms**

Ch3: Fastest & most accurate amplifier gain compression. 101 pts, src/rcvr/mismatch cal correction. 10 kHz IFBW. **450ms.**

Ch4: Fastest and most accurate amplifier noise figure measurement. 101 pts, source-corrected NF cal, 1 kHz IFBW. **2700 ms**
A common amplifier specification. A parameter used to define the transition region between the linear and nonlinear region of an active device.
PNA-X Option 086
Gain Compression Application (GCA)

GCA provides amplifier or converter gain compression data fast and accurately, at multiple frequencies, with a simple setup.

- Measure this key device specification many times faster than current methods with GCA’s SMART sweep.
- Achieve the highest measurement accuracy of any solution in the market by using mismatch correction.
- Compression methods include:
  - Compression from linear gain
  - Compression from maximum gain
  - Compression from back off
  - X/Y compression
  - Compression from saturation
Making Gain Compression Measurements On an Amplifier

- S-Parameters are part of the Standard Measurement Class.
- Gain compression is a new Measurement Class, with its own UI, Calibration and data displays, including S-Parameters.
A Typical Gain Compression Trace
2D Sweep – Sweep Power per Frequency

1 dB compression: Input power resulting in 1 drop in gain.

Gain compression is a 2D measurement: sweep power + sweep frequency.
PNA-X’s Gain Compression Application
Measure compression parameters at multiple frequencies, FAST, and in one channel, one sweep.
Compression Analysis: Pin, Pout, Compression and Gain vs Drive Power are displayed
Demonstration

Gain Compression Application
Frequency Converter Testing
Second Source for Mixer LO Signal

- **Source 1**: RF jumpers, 35 dB, 65 dB, Pulse generators
- **Source 2**: RF jumpers, 35 dB, 65 dB, Pulse generators
- **Test port 1**: OUT 1, OUT 2
- **Test port 2**: OUT 1, OUT 2
- **RF jumpers**
- **Receiver**
- **Mechanical switch**
Until Now, SMC and VMC Were Two Best Choices for Mixer/Converter Test

Scalar Mixer/Converters (SMC)
- Highest accuracy conversion-loss/gain measurements with simple setup and cal
- Removes mismatch errors during calibration and measurements by combining one-port and power-meter calibrations

Vector Mixer/Converters (VMC)
- Most accurate measurements of phase and absolute group delay
- Removes magnitude and phase errors for transmission and reflection measurements by calibrating with characterized through mixer
Inter-Modulation Distortion
PNA-X Option 087 IMD Application

Achieves **fast and accurate IMD measurements** that are easy to set up and calibrate. Features a **simple user interface** that takes advantage of PNA-X’s **internal combiner and two internal sources** with high power and low harmonics, further solidifying PNA-X as the **best solution for active-device test**.

- Measures tone powers, IMD products (dBm or dBC), and intercept points of order 2, 3, 5, 7, or 9
- Sweep Fc, tone spacing, tone power, or LO power
- Spectrum measurements eliminate need for SA
- Works on 2- or 4- port PNA-X models
Inter-Modulation Distortion: Using internal second signal source and combiner

Enable S-parameter and IMD measurement with single connection.
IMD: Two internal sources & signal combiner
Demonstration

Inter-Modulation Distortion
The Problem with Measuring Noise Figure

NFA and other analyzers measure NF in a *nominal* 50-ohm environment.

Noise parameter analysis shows us that NF varies with source impedance ($\Gamma_s$).

Test systems don’t have perfect 50-ohm source impedances.

Conventional noise figure systems introduce significant error due to non-ideal source match.
Introducing the N5242A Option 029

Vector-corrected noise figure option extends single-connection multiple-measurement capability of the PNA-X

Measure key amplifier parameters up to 26.5 GHz with a single connection (e.g. S-parameters, noise figure, compression, IMD, harmonics)

Achieve the highest measurement accuracy of any solution on the market

Agilent's unique noise-figure-calibration technique uses an ECal module as an impedance tuner to remove the effects of imperfect system source match
PNA-X’s Unique Source-Corrected Technique

PNA-X varies source match around 50 ohms using an ECal module (source-pull technique)

With resulting impedance/noise-figure pairs and vector error terms, very accurate 50-ohm noise figure ($\text{NF}_{50}$) can be calculated

Each impedance state is measured versus frequency

($Z_1, F_1$), ($Z_2, F_2$), …

Z’s measured during cal
F’s measured with DUT
2-Port PNA-X Options 219, 224, 029

Source 1

OUT 1 → Pulse modulator → OUT 2

Source 2

OUT 1 → Pulse modulator → OUT 2

Rear panel

A

35 dB

B

35 dB

Noise receivers

10 MHz - 3 GHz

3 - 26.5 GHz

LO

To receivers

DUT

Pulse generators

R1

OUT 1

OUT 2

R2

Test port 1

Source 2 Output 1

Test port 2

Source 2 Output 2

+28V

Rear panel

Mechanical switch

Agilent Technologies
Noise Figure Setup

[Image of Noise Figure Setup software interface]

- Frequency options: 24 MHz, 8.0 MHz, 4.0 MHz, 2.0 MHz, 800 kHz
- Bandwidth set to 4.0 MHz
- Number of Points: 281
- Start frequency: 10.0 MHz, Stop frequency: 26.5 GHz
- Center frequency: 13.295 GHz, Span: 26.49 GHz

- Noise Bandwidth: 4.0 MHz
- Average Number: 5

- Impedance States:
  - Input Power Level: Port 1
  - Linear Power Level: Port 2
  - Source Attenuator: 20 dB
  - Receiver Attenuator: 0 dB
  - Source Leveling: Internal

- Noise Figure Setup: 4 through 7
Example NF Measurements

- PNA-X method using source correction
- Traditional Y-factor technique
Pulsed S-Parameters

Ease of Setup
- Internal pulse modulators (one or two)
- Internal pulse generators (four)
- Very fast pulse-profile measurements (20 – 30x improvement from PNA)

Wide- or narrow-band detection
- PW ≥ 250 ns with wideband detection
- PW ≥ 33 ns with narrowband detection

Dynamic range improvements for narrowband detection
- Crystal-filter path with increased gain
- Patented software gating technique (Especially helpful for small duty cycles)
VNA Pulsed-RF Measurements

**Average Pulse**
- Magnitude and phase data averaged over duration of pulse

**Point-in-Pulse**
- Data acquired only during specified gate width and position within pulse

**Pulse Profile**
- Data acquired at uniformly spaced time positions across pulse (requires a repetitive pulse stream)

**VNA data display**
- Frequency domain
- Swept carrier
- Frequency domain
- CW
- Magnitude
- Time domain
- Phase
Defining the Acquisition Window

Narrowband detection uses hardware switches (gates) in RF or IF path to define acquisition window.

Broadband detection uses sampling period to define acquisition window.
Pulse-to-Pulse (Single Shot) Measurements

- Carrier remains fixed in frequency
- Measurement point in pulse remains fixed with respect to pulse trigger (requires wideband detection technique)
- One data point for each successive pulse, no pulses skipped
- Display magnitude and/or phase versus time
Narrowband Example with Low Duty Cycle (0.001%)
Industry-First 50 GHz Nonlinear Vector Network Analyzer (NVNA)

Vector-corrected nonlinear measurements from 10 MHz to 50 GHz

- Calibrated absolute amplitude and relative phase of measured spectra traceable to standards labs
- 50 GHz of vector-corrected bandwidth for time domain DUT waveforms of voltages and currents
- Multi-envelope domain measurements for measurement and analysis of memory effects
- X-parameter extraction into ADS X-parameter block for nonlinear simulation and design

All NVNA features and capabilities are available up to 50 GHz, enabling accurate nonlinear characterization of a broad range of devices

U9391F New 50 GHz phase calibration standard
Advanced Design System (ADS)
System Level Modeling & Design

NVNA
Nonlinear Measurements

Data File

ADS
Simulation and Design

X-parameter blocks

X-parameters enable accurate nonlinear simulation under arbitrary matching conditions…

... allowing prediction of system behavior with multiple nonlinear circuits!
X-Parameters: The Potential

Top-down design specifications
Bottom-up verification
Proof-of-concept

IC designer

X-parameters desired specs

Advanced Design System 2008
Productivity by Design

Electronic system level design

Proof-of-concept

X-parameters from simulation

Network equipment manufacturers...

X-parameters

NVNA

X-parameters

Last update: Nov 2010

Agilent Technologies
Other Features
Product Features – Receivers

Outstanding receiver compression (0.1 dB comp: +12 dBm)

• Improves dynamic linearity when measuring amplifiers
• Improves gain-compression accuracy
Product Features – User Interface

Crisply view data with 10.4” standard touch-screen, high-resolution display

Quick and easy operation using hard/soft keys or pull-down menus

Mouse zoom plus “click and drag” markers

Convenient access to USB ports for ECAl, flash drives, mouse, etc.

Eight soft keys plus “user key” for your favorite functions

Simplified set of hard keys (similar to 8753/8720/ENA)
Intuitive User Interface

**Benefit:** less time spent setting up measurements means faster time-to-insight, time-to-design, and time-to-market

- Mouse short-cuts speed setup times
  - Right-mouse click for new traces, new windows, format, stimulus, memory…
  - Easily change scale, ref level
  - Add and drag markers
  - Move marker readout
  - Drag traces between windows
  - Maximize windows or traces
- Undo key saves time recreating complicated instrument states
Product Features – Rear Panel

CPU = 2 GHz Core 2 Duo, 2 GB memory

Computer Processor

13 MHz - 26.5 GHz
3.2 GHz - 26.5 GHz
Operation in Secure Environments
PNA/PNA-X Series Provides Industry-Leading Applications

• Applications provide **accuracy, speed, and convenience**

• **PNA-X exclusive applications**
  • Noise figure
  • Gain compression
  • IMD
  • True-mode stimulus
  • Nonlinear vector network analysis

• **Applications across entire PNA series**
  • Pulsed S-parameters
  • Frequency converters (including embedded-LOs)
  • Multiport calibration
  • Time domain
Agilent Technologies 40 Years of Network Analyzer Innovations

1967
8410A

1975
8542A Automation

1984
8510A set the industry standard

1986
8753 Series New economy entry into RF market

1988
8720 Series New economy entry into the Microwave

1991
8711 Series Low Frequency

1996
8510XF Single sweep up 110GHz

2000
PNA: New standard of performance

2001
ENA

2007-2010
PNA-X/NVNA

Agilent Technologies 40 Years of Network Analyzer Innovations
Agilent Vector Network Analyzer Portfolio

Test Accessories

FieldFox
Portable RF/MW Analyzer

ENA
High performance RF

ENA-L
Economy RF

PNA-X, NVNA
Most advanced and flexible

PNA
High performance microwave

PNA-L
Economy microwave

Mm-Wave
Up to THz

PNA-X Receiver
Antenna measurements

Industry’s Broadest Price/Performance Choices

… plus measurement applications!
The network analyzer portfolio from Agilent delivers an unparalleled combination of performance and flexibility for a broad range of applications from 5 Hz up to 1.05 THz!

**ENA Series - RF**
- 20 GHz
- 8.5 GHz
- 4.5 GHz
- 1.5 GHz

**PNA Series - Microwave**
- Up to 1.05 THz!
- 325 GHz
- 110 GHz
- 67 GHz
- 50 GHz
- 40 GHz
- 26.5 GHz
- 20 GHz
- 13.5 GHz
- 6 GHz