Basics of RF Amplifier Test with the Vector Network Analyzer (VNA)

Taku Hirato
Product Marketing Engineer
CTD-Kobe, EMG
Agilent Technologies
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Objectives

Understand what types of amplifier measurements are made with RF VNAs.

• S-parameter / Stability factor (K-factor)
• Measurements with power leveling
• Gain compression (P1dB compression point)
• Pulsed-RF measurements
• Intermodulation distortion (IMD)

Understand associated key features of the modern VNAs
Agilent VNA Portfolio

Amplifier Test - Measurement Parameters

• S-parameter / Stability factor (K-factor)
• Measurement with power leveling
• Gain compression (P1dB compression point)
• Pulsed-RF measurement
• Intermodulation Distortion (IMD)

Summary
Agilent VNA solutions

PNA-X, NVNA
Industry-leading performance
10 M to 13.5/26.5/43.5/50/67 GHz
Banded mm-wave to 2 THz

PNA
Performance VNA
10 M to 20, 40, 50, 67, 110 GHz
Banded mm-wave to 2 THz

PNA-L
World’s most capable value VNA
300 kHz to 6, 13.5, 20 GHz
10 MHz to 40, 50 GHz

PNA-X receiver
8530A replacement

Mm-wave solutions
Up to 2 THz

ENASeries

E5072A
Best performance ENA
30 kHz to 4.5, 8.5 GHz

E5071C
World’s most popular economy VNA
9 kHz to 4.5, 8.5 GHz
300 kHz to 20.0 GHz

E5071B
NA + ZA in one-box
5 Hz to 3 GHz
Low cost RF VNA
100 k to 1.5/3.0 GHz

FieldFox
Handheld RF Analyzer
5 Hz to 4/6 GHz

Agilent Technologies
E5072A = 8753x + 2-port RF E5071C and More.

**E5072A**

Configurable test set
Direct receiver access (S/R/A/B port)
Higher power output (up to +20 dBm)
High-gain amp measurement (with very low power down to -85 dBm)

Enhanced power calibrations (Power cal / Receiver cal / Receiver leveling)
>150 dB wide dynamic range
Wide power range (available from -109 to +20 dBm)

**HP/Agilent 8753x**

Basic 2-port measurement
Frequency Offset Mode (FOM)
Time domain analysis

**E5071C RF Options (4.5 / 6.5 / 8.5 GHz)**

Faster speed
Better performance
Powerful software analysis
Connectivity
Upgrade of all options

**Multiport (>2-port) Opt. TDR**

- Anticipate
- Accelerate
- Achieve
ENA Series Application Mapping

Wireless
- Passive
  - Antenna evaluation
  - Differential components evaluation
  - Multiport devices test
  - BTS filter tuning test
- Active
  - RF amp test
  - Front end module test
  - Chip antenna test
  - Mixer test
  - Chip antenna test
  - RFID

Wireline
- Active
  - DC/DC converter evaluation
  - Impedance evaluation
- Power integrity
  - RF amp test

Computer
- Inter connects
  - High speed digital
  - Cable/PCB test with Option TDR
- DC/DC converter evaluation

Automotive
- Inter connects
  - High speed digital
  - Cable/PCB test with Option TDR
- Power amp test

Industry/Science/Medical
- High speed digital
  - Cable/PCB test with Option TDR
- Power amp test
  - Gain/Phase measurements
  - EMC components evaluation
  - Power amp test
  - CATV 75 ohm components
  - MRI coil tests
  - Coax. cable test

www.agilent.com/find/ena

Lab.
- Antenna evaluation
- Differential components evaluation
- Multiport devices test
- BTS filter tuning test
- Chip antenna test
- Mixer test

Production
- Antenna evaluation
- Differential components evaluation
- Multiport devices test
- BTS filter tuning test
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- Mixer test
ENA Series Application Mapping

E5072A is best suited for amplifier test

Wireless
- Passive
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  - Chip antenna test
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Lab.
- RF amp test
- Wire Line Industry/Science/Medical

Production
- RF amp test
- Front end module test

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Anticipate Accelerate Achieve
Agilent VNA Portfolio

Amplifier Test - Measurement Parameters

- S-parameter / Stability factor (K-factor)
  - Measurement with power leveling
  - Gain compression (P1dB compression point)
  - Pulsed-RF measurement
  - Intermodulation Distortion (IMD)

Summary
Amplifier Test - S-parameters

Linear transmission and reflection measurements are performed with a single connection with the VNA.

Gain, gain flatness, phase, group delay, \((S_{21})\)

Input match, input impedance, VSWR, \((S_{11})\)

Output match, output impedance, VSWR, \((S_{22})\)

Reverse isolation \((S_{12})\)
**Amplifier Test - Stability Factor (K-factor)**

**K-factor** calculated from all the four S-parameters (S11, S12, S21 and S22) and represents the stability of amplifiers.

**Definition of K-factor**

\[
K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|}
\]

*where*

\[
\Delta = S_{11}S_{22} - S_{12}S_{21}
\]

Note: When K-factor > 1 while delta is < 1, the amplifier is unconditionally stable for any load.

**Measurement Challenges:**

- K-factor is calculated from all four S-parameters and should be displayed in real-time.
- All four S-parameters must be accurate for calculation of K-factor.
VNA Features

Equation Editor

- Computes measurement results and add a new trace to the display.
- Equations can be based on any combination of existing traces or parameters or constants.
- Easy setup with pre-defined parameters such as K-factor, μ-factor, maximum available power gain, or maximum stable power gain etc.
Amplifier Test - S-parameters

High-gain amplifier outputs high-power above the maximum input level of VNA’s receivers.

Measurement Challenges:
• Dealing with high-gain and high output power of the amplifiers.

=> Useful VNA Features
• Uncoupled power
• Configurable test set / Direct receiver access
VNA Features

Uncoupled power
- Different output power level can be set for port 1 & 2 with independent built-in attenuators.
- Easy characterization of high-gain power amp without an external attenuator on output port.
- More accurate reverse measurement (i.e. S12, S22) with wider dynamic range.

Block diagram of Agilent E5072A

ATT = 40 dB (Port 1)
-85 dBm

DUT

ATT = 0 dB (Port 2)
0 dBm
S-parameters & K-factor
Measurement Example

DUT: 30 dB RF Amp

**Coupled power**
(Port 1 = Port 2 = -40 dBm)

**Uncoupled power**
(Port 1 = -40 dBm, Port 2 = 0 dBm)

More accurate S12 measurement with **uncoupled power** results in better trace of calculated K-factor.
S-parameters (High-power amplifier) Configuration with output attenuator

Dealing with high output power from high-power amplifier is a challenge.

Typical 2-port configuration with large attenuation

Measurement example of high-power amplifier

Measurement Challenge:
• Large output attenuation is necessary for receiver protection; S/N ratio of $S_{22}$ is significantly degraded because of very low signal input to receiver B.
VNA Features

Configurable Test Set / Direct Receiver Access
- The VNA with configurable test set option is associated with six SMA connectors on front.
- The test configuration can be modified by accessing source / receivers directly.

Agilent E5072A
An alternative configuration is provided by using the direct receiver access and appropriate external components. More accurate reverse measurements (i.e. S22) can be performed.
Higher input power to the receiver B means guarantees the enough S/N ratio for reverse measurements (i.e. S22) with a test configuration using direct receiver access.
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Amplifier Test - Measurement Parameters

• S-parameter / Stability factor (K-factor)
• Measurement with power leveling
  • Gain compression (P1dB compression point)
  • Pulsed-RF measurement
  • Intermodulation Distortion (IMD)

Summary
Amplifier test with leveled power

Some power-sensitive amplifiers are characterized when its input power (Pin) or output power (Pout) across frequency range is very flat at a specified value.

Measurement Challenges:
- Power leveling of DUT’s input or output power within the tolerance of DUT’s specifications.
Measurements with leveled power
Current solution for power leveling

Typical setup of leveling output power ($P_{out}$)

Procedure of leveling output power
1. SG’s source power is set for a certain measurement point.
2. DUT’s output power ($P_{out}$) is monitored by power sensor via coupler.
3. SG’s output power is calibrated to adjust $P_{out}$ within the DUT’s specification.
4. The power leveling process is continued for all measurement points.

Measurement Challenges:
- The leveling process takes long time. Necessary to reduce time for faster measurement.
VNA features

Receiver leveling

- Adjusts the source power level across frequency or power sweep range using its receiver measurements.
- The complexity of rack and stack test system for external power leveling can be reduced.

Leveling with rack & stack system

Leveling with VNA’s receiver leveling

Receiver leveling offers fast leveling of DUT’s output power with a single instrument.
Measurement with leveled power

DUT: 30 dB RF Amplifier. Target power (Pin or Pout) = -10 dBm.

Leveled input power (Pin)

Leveled output power (Pout)
(with receiver leveling with B)

- DUT’s Pin and Pout can be monitored with absolute measurements with the VNA
- Receiver leveling of the VNA accurately adjusts Pin & Pout at target power level (i.e. -10 dBm)
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Amplifier Test - Measurement Parameters

- S-parameter / Stability factor (K-factor)
- Measurement with power leveling
- Gain compression (P1dB compression point)
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Summary
What is gain compression?

- Parameter to define the transition between the linear and nonlinear region of an active device.
- The compression point is observed as x dB drop in the gain with VNA's power sweep.
The higher, the better!

Enough margin of source power capability is needed for analyzers.

ex.) Long-distance test

Signal loss associated with:
Long RF cables, probes, min loss pads (50-to-75 ohm conversion) etc.

Measurement Challenges:
Driving DUT with high power
- Due to loss in the signal path, necessary to boost power to DUT’s input for compression measurements.
VNA features

Higher output power

- The E5072A has the maximum power with $+20$ dBm available from the test port. (up to 1 GHz)
- Wide power sweep (> 65 dB) can be done for compression test with a single sweep.

Output power level comparison

$>65$ dB wide power sweep
Gain compression with high-power

External booster amps are needed for higher power than the analyzer's source.

ex.) High-power test system with a booster amp

![Diagram showing SG, Booster amp, DUT, SA and their connections]

- **Measurement Challenges:**
  - **Power leveling** - Eliminating short-term drift of a booster amplifier’s gain; variation of input power to DUT.

When temperature changes, the gain changes..

Actual input power becomes **out of tolerance.**
Gain compression with high-power

Power leveling

Typical setup of leveling high input power (Pin)

1. SG’s source power is set for a certain measurement point.
2. Pin is monitored by power sensor via high-power coupler.
3. SG’s output power is calibrated to adjust Pin within the DUT’s specification / tolerance.
4. The power leveling is performed periodically. (i.e. after ambient temperature & booster amp’s gain changes.)

Measurement Challenges:
- Power leveling process takes very long time!
- Test configuration is complicated; necessary to lower overall cost of test systems.
VNA features

Receiver leveling

- Adjusts the source power level across frequency or power sweep range using its receiver measurements.
- The complexity of rack and stack test system for external power leveling can be reduced.

Leveling with rack & stack system

- SG’s source power is adjusted.
- Power Sensor
- Coupler
- DUT
- SA
- System Controller

Leveling with VNA’s receiver leveling

- E5072A
- ATT (Optional)
- Booster amp
- Coupler
- Pin
- DUT

Receiver leveling offers fast and accurate leveling to compensate a booster amp’s short-term drift with a simple connection.
Leveled high-power with receiver leveling

Configuration of leveled high-power test

Input power (Pin) with receiver leveling ON & OFF

DUT’s Pin is accurately adjusted at target power level of +43 dBm by using receiver leveling with the VNA.

Note: frequency sweep is performed to monitor Pin over frequency.
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Amplifier Test - Measurement Parameters

• S-parameter / Stability factor (K-factor)
• Measurement with power leveling
• Gain compression (P1dB compression point)

→ Pulsed-RF measurement
• Intermodulation Distortion (IMD)

Summary
Why Pulsed Measurement?

- Device may behave differently between CW and pulsed signals
  - Changes during pulse might affect RF performance

- CW signal would destroy your DUT
  - High-power amplifiers not designed for CW operation
  - On-wafer device often lack adequate heat sinking
  - Pulsed test power level can be the same as actual operation

Example) Pulsed-RF measurement for GSM Power Amp with VNA
Pulsed-RF Measurement with ENA
Test Configuration Example

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**Agilent 81110A**
Pulse/Pattern Generator

- **Ref In**
- **Ref Out**
- **Trigger Out**
- **Output 1**

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**Agilent E5072A**
ENA Series Network Analyzer

- **Ext Trig In**
- **Ref Out**
- **Port 1**
- **Port 2**

---

**Pulse Modulator**

- **RF In**
- **RF Out**

---

**Control Voltage**

**Attenuator (Optional)**

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**DUT**

- **RF On**
- **RF On**

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Data acquisition at VNA’s receivers

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Time
Pulsed Measurement with VNA

Timing Chart

Pulse Generator Trigger OUT

Pulsed RF Signal from pulse generator

Delay

Pulse Width

Period

RF On

Duty cycle (%)

VNA Trigger Input

VNA Data Acquisition

Sampling / Data acquisition

Td

Ts

Ta

Td
Pulsed-RF Measurement
Measurement Example

Gain of 30 dB amplifier: Pulse Width = 5 us, Period = 100 us.

Synchronized pulsed-RF measurement shows the correct frequency response of the DUT in pulsed operation.
Pulsed-RF (with receiver leveling)

Configuration

Amplifier measurements with power leveling under pulsed condition.

Typical setup of leveling input power (**Pin**)

**Measurement Challenges:**
- Accurate power leveling of input power (**Pin**) in pulsed operation.
Pulsed-RF (with receiver leveling)
Measurement Example

Gain of 30 dB amplifier: Pulse Width = 5 us, Period = 100 us.

- Input power level at DUT is adjusted by receiver leveling.
- Useful for characterization of power-dependent performance or nonlinear operation in pulse mode.
Agilent VNA Portfolio

Amplifier Test - Measurement Parameters

• S-parameter / Stability factor (K-factor)
• Measurement with power leveling
• Gain compression (P1dB compression point)
• Pulsed-RF measurement
• Intermodulation Distortion (IMD)

Summary
What is intermodulation distortion (IMD)?

- A measure of nonlinearity of amplifiers.
- Two or more tones applied to an amplifier and produce additional intermodulation products.

\[ F_{IMD} = n \times F_1 + m \times F_2 \]
IMD Measurement

Current solution

Typical setup of IMD measurements

Measurement Challenges:
- It requires a controller to synchronize multiple instruments.
- If many frequencies must be tested, test time is increased dramatically.
VNA features

**Frequency Offset Mode**

- Sets different frequency range for the source and receivers.
- Can be used for harmonics or intermodulation distortion (IMD) measurements with the VNA.

**Normal Sweep**

- Source and receiver are tuned at the same frequency range (for harmonics, IMD test etc.)

**Frequency-offset Sweep**

- Source and receiver are tuned at the different frequency range (for harmonics, IMD test etc.)
IMD Measurement

Configuration of IMD measurement with VNA

- SG
- ENA
- DUT
- Combiner
- Attenuator (Optional)
- USB/GPIB Interface (i.e. 82357B)

Measurement example (sweep delta)

- f1 (SG)
- f2 (ENA)
- Lo IM3

Power levels of main tones and IM products in swept frequencies can be monitored with the VNA’s absolute measurements.
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Amplifier Test - Measurement Parameters

• S-parameter / Stability factor (K-factor)
• Measurement with power leveling
• Gain compression (P1dB compression point)
• Pulsed-RF measurement
• Intermodulation Distortion (IMD)

➡️ Summary
Summary

• Modern VNAs have many useful features for amplifier characterization that enable you to:

1. Reconfigure your test system by reducing complexity
2. Simplify time-consuming measurement steps for higher throughput
3. Perform efficient and accurate measurements
New application note for RF amplifier test with VNA is available!

Basics of RF Amplifier Measurements with the E5072A (Part Number 5990-9974EN)

High-power Measurements with the E5072A (Part Number 5990-8005EN)

Visit: www.agilent.com/find/e5072a
Questions?
ENA series value add campaign

Buy now and get **50% OFF** on an USB power sensor!

Promotion availability: January 1, 2012 to **June 30, 2012**.

### Agilent E5072A ENA Series Network Analyzer
- Best performance ENA
- 2-port, to 4.5 & 8.5 GHz
- Power calibration techniques (i.e. receiver leveling)

### Agilent U2000 Series USB Power Sensors
- **Necessary for power calibrations with the E5072A**
- USB connectivity for automatic plug & play
- 9 k to 24 GHz and -60 to +44 dBm (sensor option dependent)
Resources

E5072A information
• ENA series web page: http://www.agilent.com/find/ena
• E5072A web page: http://www.agilent.com/find/e5072a
• E5072A Configuration Guide: Part number 5990-8001EN
• E5072A Data Sheet: Part number 5990-8002EN
• E5072A Quick Fact Sheet: Part number 5990-8003EN
• E5072A Technical Overview: Part number 5990-8004EN

Application Note
• High-power Measurement using the E5072A (Part Number 5990-8005EN)
• Basics of RF Amplifier Measurements with the E5072A (Part Number 5990-9974EN) New!

• TIP: to find any publications online simply enter Pub # or title in search field at: www.agilent.com
Power-Added Efficiency (PAE)

- A measure of the power conversion efficiency of amplifiers.
- The ratio of RF power gain and consumption power.

**Definition of PAE**

\[
PAE = \frac{P_{out} - P_{in}}{P_{dc}} \times 100 \quad (\%)
\]

where

- \( P_{out} \) = fundamental output power
- \( P_{in} \) = RF drive power
- \( P_{dc} \) = DC supplied power

**PAE represents:**
- the efficiency of power amplifiers / battery operation time of handset.
- main power consumptions and electricity / cooling cost in BTS systems.

=> PAE is an important parameter for all amplifiers.
VNA features

Receiver calibration

- Necessary for **absolute measurements** using the VNA’s receivers.

An example of a test setup for PAE measurements.

AUX connectors (AUX1 & AUX2) on real panel of the E5072A (BNC, +10 V range)

DC power supply → Sensing circuit → DUT → Port 1

Optional Attenuator

Port 2
<table>
<thead>
<tr>
<th>Tr#</th>
<th>Parameter</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S21 (Log Mag)</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>S21 (Phase)</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>R1</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td>N/A</td>
</tr>
<tr>
<td>5</td>
<td>Aux Input 1 (AI1)</td>
<td>N/A</td>
</tr>
<tr>
<td>6</td>
<td>Aux Input 2 (AI2)</td>
<td>N/A</td>
</tr>
<tr>
<td>7</td>
<td>Vsupp</td>
<td>data(5)</td>
</tr>
<tr>
<td>8</td>
<td>Isupp</td>
<td>(data(5) - data(6)) / R</td>
</tr>
<tr>
<td></td>
<td>Pout</td>
<td>(0.001 * pow(mag(data(4)), 2))</td>
</tr>
<tr>
<td></td>
<td>Pin</td>
<td>(0.001 * pow(mag(data(4)), 2)) / pow(mag(data(1)), 2)</td>
</tr>
<tr>
<td></td>
<td>Pdc</td>
<td>(data(5)*(data(5)-data(6)) / R)</td>
</tr>
<tr>
<td>9</td>
<td>PAE</td>
<td>100 * ((0.001 * pow(mag(data(4)), 2)) - (0.001 * pow(mag(data(4)), 2)) / pow(mag(data(1)), 2)) / (data(5) *(data(5)-data(6)) / R)</td>
</tr>
</tbody>
</table>

Note “R” in the equations is the value of a sensing resistor.
PAE Measurement Example

- DUT: Mini-Circuits ZRL-2400LN+ (1 to 2.4 GHz, 30 dB gain), 20 dB ATT is added on port 2.
- Frequency (CW) = 1.126 GHz, IFBW = 1 kHz, NOP = 51, Input power (Pin) = -15 to +5 dBm, Response thru cal.
- Vdc_supply = 10 V

Gain compression / AM-to-PM / Pin / Pout / PAE

PAE calculated by equation editor is displayed.
What is harmonic distortion?

• Specified to describe nonlinear behavior of amplifiers.
• Harmonic level is defined as the difference in absolute power level between the fundamental and the harmonics.
• Expressed in dBc (dB relative to carrier) for a specified input or output power.
Harmonic Distortion

- Using a SG and a SA with CW signals.
- If many frequencies must be tested, test time is increased dramatically.

VNA with **frequency-offset mode (FOM) option** can set different frequencies at the source and receiver.
- **Real-time** swept frequency / power harmonics measurements can be performed.
- Source power calibration and receiver calibration is available with VNA for accurate absolute power measurements.
Harmonic Distortion Measurement results

Fundamental (f1)
2nd harmonic (f2)
3rd harmonic (f3)

Fast swept measurements of harmonic distortion measurements.

Swept frequency
Swept input power

Fundamental frequency (Hz)
Input power (dBm)

Note: DUT’s harmonics are displayed with data trace; ENA’s source harmonics (filtered with LPF) are displayed with memory trace.
VNA features

**Measurement Wizard**

- ENA series’ VBA program speeds up measurements of RF amplifiers.
- Key parameters of amplifiers: S-parameters, harmonics, gain compression (CW or Swept frequency) measurements.
- Can be downloaded on Agilent.com (www.agilent.com/find/enavba)
VNA features
Measurement using wizard

Measurement wizard for swept harmonic distortion for the ENA is available on Agilent website.
Visit: www.agilent.com/find/enavba
VNA features

Amplifier Measurement Wizard
- Key parameters of amplifiers: S-parameters (K-factor), harmonics, gain compression (CW or Swept frequency).

S-parameter & K-factor
- S11
- S12
- S21
- S22
- K-factor

Swept Harmonics
- Fund.
- 2nd
- 3rd
- 4th
- 5th
- Harm. (dBc)

Gain Compression
- CW
- AM-PM vs. Pin
- Pout @ PxdB vs. Pin
- Swept
- Gain vs. Pin
- Pout vs. Pin
- Pin & Pout @ PxdB vs. Frequency

All the basic amplifier measurements with a simple setup!
IMD Measurement
Solution with VNA

- Using two SGs and a SA with CW signals.
- It requires a controller to synchronize instruments.
- If many frequencies must be tested, **test time is increased dramatically**.

2x SG + SA

- ENA with **frequency-offset mode (FOM) option** can set different frequencies at the source and receiver.
- **Real-time** swept frequency IMD measurements can be performed.
- Source power calibration and receiver calibration is available with VNA for **accurate** absolute power measurements.

SG + VNA
VNA Features

Power calibration

1. Source power calibration
   • The VNA’s source power level is calibrated using a power sensor to get accurate input power level to DUT.
   • Power level accuracy is directly dependent on the accuracy of the power sensor used.

2. Receiver calibration
   • Necessary for absolute measurements in dBm.
   • Must have a power-calibrated source at the same frequency range.
   • Mathematically removes frequency response in the receiver path and adjusts the VNA’s reading to the same as power level in dBm at the calibration plane.

3. Receiver leveling
   • Before each measurement sweep, background sweeps are performed to measure power at the receiver.
   • Power measurements at the receiver are used to adjust the VNA’s source power level.
   • Accurate power level adjustment by using high receiver linearity of VNA.
VNA Features (E5072A)

Source power calibration

- You can expect the power at the point of calibration to be within the range of the uncertainty of the power sensor used.
- At each data point, power is measured using the power meter and the source power level is adjusted until the reading of the power sensor is within the tolerance or the max iteration has been met.

<table>
<thead>
<tr>
<th>Measured Port Power at cal plane (in dBm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Diagram of power measurements and target level]</td>
</tr>
</tbody>
</table>

- **Uncorrected power**
- **Corrected power**

**Target Power Level**

- **Num of Readings**: Sets the number of power level measurements. (Averaging factor)
- **Tolerance**: Maximum desired deviation from the specified target power.
- **Loss Compen**: Compensates for losses when using an attenuator to connect the power sensor.
- **Power Offset**: A gain or Loss to account for components between the port and cal plane. For example, the positive value is set if a booster amp is inserted for high-power measurements. Source power + Power offset = Target Power
VNA features

Source power calibration

- Calibration transfers the accuracy of the power sensor, and sets the DUT’s input power to be a specified level.
- At each data point, source power level is adjusted until the reading of the power sensor is within the specified tolerance.

Measured power by power sensor (in dBm)

Target Input Power (Pin)

Uncorrected power
Corrected power

Frequency

tolerance
VNA features

Receiver calibration

- Necessary for **absolute measurements** using the VNA's receivers.
- Mathematically removes frequency response in the receiver path and adjusts the reading to the same as the targeted power level.
- Must have a power-calibrated source at the same frequency.

![Diagram showing power levels and attenuation](image)

- Measured power at receiver B (in dBm)
- Calibrated power
- Uncalibrated power
- Frequency

Power = +0 dBm (e.g. 20 dB)
E5072A key features

**Configurable test set**
- Easy access to source and receivers
- Accurate high-power measurement
- Receiver leveling with internal receivers

**Wide output power range**
- High output power (max +20 dBm)
- Settable from -109 dBm to +20 dBm
- Independent output power for port 1 & 2

**High receiver sensitivity**
- Extended dynamic range (> 150 dB)
- Accurate low-power measurements

**Frequency offset measurement**
- Harmonics measurement
- Vector mixer calibration (VMC)
- Scalar mixer calibration (SMC)

**Compatible with 8753 & E5071C**
- 100% code compatible with E5071C
- 8753 code emulator (cXL)
- Same size, U/I etc.

**Upgradability**
- Upgrade among all hardware & software options
## Comparison with 8753ES & E5071C

### Advantages

<table>
<thead>
<tr>
<th></th>
<th>8753ES</th>
<th>2-port E5071C (opt.24x, 26x, 28x)</th>
<th>E5072A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test frequency</strong></td>
<td>30 k to 3 G / 6 GHz</td>
<td>9 k to 4.5 / 6.5 / 8.5 GHz (without bias-tees, opt.xx0) 100 k to 4.5 / 6.5 / 8.5 GHz (with bias-tees, opt.xx5)</td>
<td>30 k to 4.5 / 8.5 GHz (with bias-tees) (Settable down to 9 kHz)</td>
</tr>
<tr>
<td><strong>Configurable test set</strong></td>
<td>Yes (Option 014)</td>
<td>No</td>
<td>Yes (standard)</td>
</tr>
<tr>
<td></td>
<td>Max output power</td>
<td>Max output power</td>
<td>Max output power</td>
</tr>
<tr>
<td></td>
<td>+10 dBm (Option 014)</td>
<td>+10 dBm (up to 5 GHz)</td>
<td>+16 dBm (spec, up to 3 GHz) +20 dBm (SPD, 300 k to 1 GHz)</td>
</tr>
<tr>
<td></td>
<td>+20 dBm (Option 011)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power range</strong></td>
<td>-85 to +10 dBm (Standard)</td>
<td>-55 to +10 dBm</td>
<td>-85 to +16 dBm (spec, up to 3 GHz) -109 to +20 dBm (settable)</td>
</tr>
<tr>
<td></td>
<td>(16 M to 3 GHz)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dynamic range</strong></td>
<td>110 dB</td>
<td>123 dB spec, 130 dB SPD (10 M to 6 GHz)</td>
<td>123 dB spec,130 dB SPD (10 M to 6 GHz)</td>
</tr>
<tr>
<td>(IFBW = 10 Hz)</td>
<td>(16 M to 3 GHz)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Extended dynamic range</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>151 dB (SPD, 10 M to 3 GHz)</td>
</tr>
<tr>
<td>(IFBW = 10 Hz)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>IFBW</strong></td>
<td>10 Hz to 6 kHz</td>
<td>10 Hz to 500 kHz</td>
<td>10 Hz to 500 kHz</td>
</tr>
<tr>
<td><strong>Cycle Time</strong></td>
<td>836 ms (IFBW = 6 kHz)</td>
<td>43 ms (IFBW = 500 kHz)</td>
<td>33 ms (IFBW = 500 kHz)</td>
</tr>
<tr>
<td>(Full 2-port Cal, 1601 pt, 1 to 1.2 GHz)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bias tee current</strong></td>
<td>200 mA (spec)</td>
<td>200 mA (spec)</td>
<td>300 mA (spec)</td>
</tr>
<tr>
<td></td>
<td>1 A (damage level)</td>
<td>500 mA (damage level)</td>
<td>1 A (damage level)</td>
</tr>
<tr>
<td><strong>Receiver leveling</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Software Options</strong></td>
<td>Time domain, FOM</td>
<td>Time domain analysis, FOM, Enhanced time domain analysis</td>
<td>Time Domain, FOM</td>
</tr>
<tr>
<td><strong>Upgradability</strong></td>
<td>No</td>
<td>Yes (among all options)</td>
<td>Yes (among all options)</td>
</tr>
</tbody>
</table>

Note: SPD or Supplemental Performance Data represents the value that is most likely occurs. Not guaranteed by the product warranty.

### Advantages

E5072A combines 8753ES & E5071C and so much more.
## Comparison Chart of the ENA Series

### Advantages

<table>
<thead>
<tr>
<th>Features / Functions</th>
<th>E5071C 2-port RF Options (opt.24x, 26x, 28x)</th>
<th>E5072A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configurable test set (Direct receiver access)</td>
<td>No</td>
<td>Yes (standard)</td>
</tr>
<tr>
<td>Uncoupled Power (with source attenuators)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Max Output Power</td>
<td>+10 dBm (up to 5 GHz)</td>
<td>+16 dBm (spec, up to 3 GHz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+20 dBm (SPD, 300 k to 1 GHz)</td>
</tr>
<tr>
<td>Power Calibration</td>
<td>Yes</td>
<td>Yes (Most accurate with tolerance and max iteration)</td>
</tr>
<tr>
<td>Receiver Calibration</td>
<td>Yes</td>
<td>Yes (with four independent receivers)</td>
</tr>
<tr>
<td>Receiver Leveling</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Harmonic distortion</td>
<td>Yes (with FOM option)</td>
<td>Yes (with FOM option)</td>
</tr>
<tr>
<td>Pulsed-RF</td>
<td>Yes (wide pulse width)</td>
<td>Yes (wide pulse width)</td>
</tr>
<tr>
<td>Amplifier measurement wizard</td>
<td>Yes</td>
<td>Yes (High-power measurement is also supported.)</td>
</tr>
<tr>
<td>Equation Editor</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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# E5072A Power Handling Capability

As high power levels can damage the instrument and it is costly to repair, it is important to understand the **power handling capability** of each component in the VNA’s signal path.

Ex.) E5072A port performance

<table>
<thead>
<tr>
<th>Connector</th>
<th>RF Damage Level (Typ.)</th>
<th>DC Damage Level (Typ.)</th>
<th>0.1 dB Compression Level (SPD*)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test Port 1 &amp; 2</strong></td>
<td>+26 dBm</td>
<td>-35 VDC</td>
<td>+6 dBm (30 k to 300 kHz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+16 dBm (300 k to 2 GHz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+14 dBm (2 G to 6 GHz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+10 dBm (6 G to 8.5 GHz)</td>
</tr>
<tr>
<td><strong>CPLR ARM</strong></td>
<td>+15 dBm</td>
<td>0 VDC</td>
<td>-</td>
</tr>
<tr>
<td><strong>RCVR A IN, RCVR B IN</strong></td>
<td>+15 dBm</td>
<td>-16 VDC</td>
<td>-15 dBm (30 k to 300 kHz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-10 dBm (300 k to 8.5 GHz)</td>
<td></td>
</tr>
<tr>
<td><strong>SOURCE OUT (Port 1 &amp; 2)</strong></td>
<td>+26 dBm</td>
<td>0 VDC</td>
<td>-</td>
</tr>
<tr>
<td><strong>CPLR THRU (Port 1 &amp; 2)</strong></td>
<td>+26 dBm</td>
<td>-35 VDC</td>
<td>-</td>
</tr>
<tr>
<td><strong>REF 1/2 SOURCE OUT</strong></td>
<td>+15 dBm</td>
<td>0 VDC</td>
<td>-</td>
</tr>
<tr>
<td><strong>RCVR R1 IN, RCVR R2 IN</strong></td>
<td>+15 dBm</td>
<td>-16 VDC</td>
<td>-15 dBm (30 k to 300 kHz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-10 dBm (300 k to 8.5 GHz)</td>
<td></td>
</tr>
</tbody>
</table>

* SPD or supplemental performance data represents the value of a parameter that is most likely to occur, not guaranteed by the product warranty.