

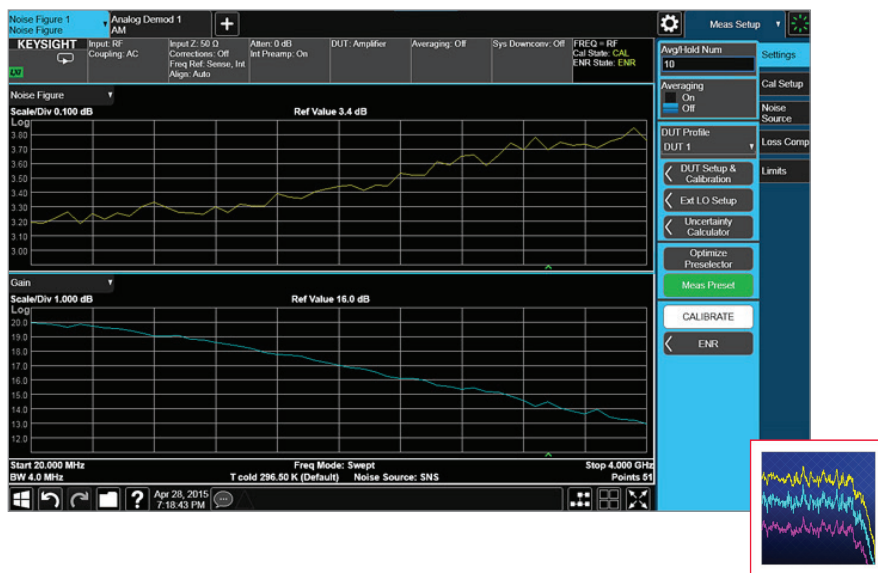
Keysight Technologies

Noise Figure

X-Series Measurement App, Multi-Touch

N9069C

Technical Overview



- Characterize noise figure and gain of connectorized devices and system blocks with graph, meter, and table layouts and built-in uncertainty calculator
- Provide fully-specified measurements with optional internal preamp; improved specifications with external USB preamp
- Speed up multi-DUT measurements with multi-DUT calibration and measurement profiles
- Extend noise figure measurements to 110 GHz (Option 526 or greater required) with Keysight's K-Series block downconverters
- Use multi-touch front panel user interface or SCPI remote interface
- Extend test assets with transportable licenses between all X-Series signal analyzers with multi-touch UI

Noise Figure Measurement Application

Noise figure is one of the fundamental parameters that differentiates one system, amplifier, or transistor from another. To minimize the problems resulting from noise generated in receiver systems, engineers can either make a weak signal stronger, or reduce the noise of that system or its individual components. The Keysight Technologies, Inc. N9069C noise figure measurement application offers development engineers a simple tool to make accurate and repeatable noise figure measurements. The speed of this application also allows manufacturing engineers to rapidly measure any one of the following in their test racks:

- Noise figure/factor
- Gain
- Effective temperature
- Y-factor
- Hot/cold power density

The noise figure application utilizes the Y-factor method for calculating noise figure. By using a noise source, an X-Series signal analyzer can quickly determine the noise of the device under test. This method is very simple, as it utilizes a ratio of two noise power levels: one measured with the noise source ON and the other with the noise source OFF.

Preamps are available to reduce the uncertainty of Y-factor noise figure measurements. With an optional preamp installed in an X-Series signal analyzer or standard with N8973/N8974/N8975/N8976B NFA X-Series, you can obtain better noise figure measurements. NFA X-Series specifications are not included in this document. For those specifications, please visit www.keysight.com/find/NFA_X-series_specifications.

X-Series measurement applications increase the capability and functionality of Keysight signal analyzers to speed time to insight. They provide essential measurements for specific tasks in general-purpose, cellular communications, wireless connectivity and digital video applications, covering more than 40 standards or modulation types. Applications are supported on both benchtop and modular, with the only difference being the level of performance achieved by the hardware you select.

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Make fast, accurate noise figure measurements with NFA

Performing accurate noise figure measurements start with a solid understanding of the uncertainty contributors - your components, subsystems and test equipment. The NFA X-Series noise figure analyzers are the simple way to make fast, accurate and repeatable noise figure measurements up to 40 GHz. With built-in expertise, ease of use features and a best-in-class USB preamplifier, our NFA's help you easily set up complex measurements - providing you with repeatable and reliable results while minimizing the overall uncertainty for your noise figure measurement challenges.



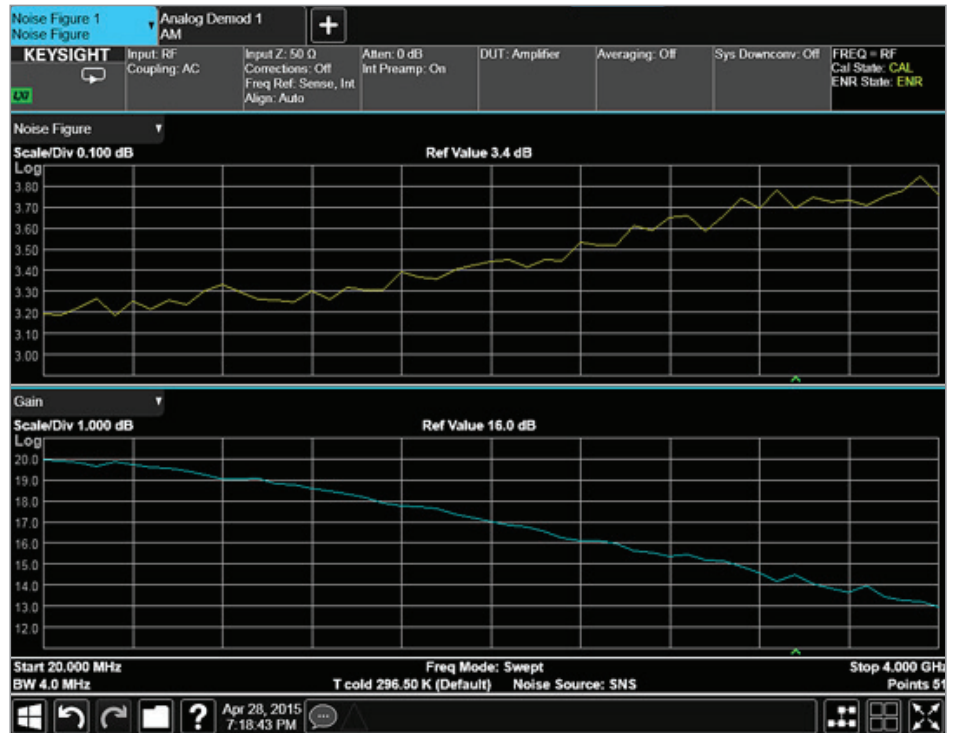
Learn more at:

www.keysight.com/find/nfa

Top Features

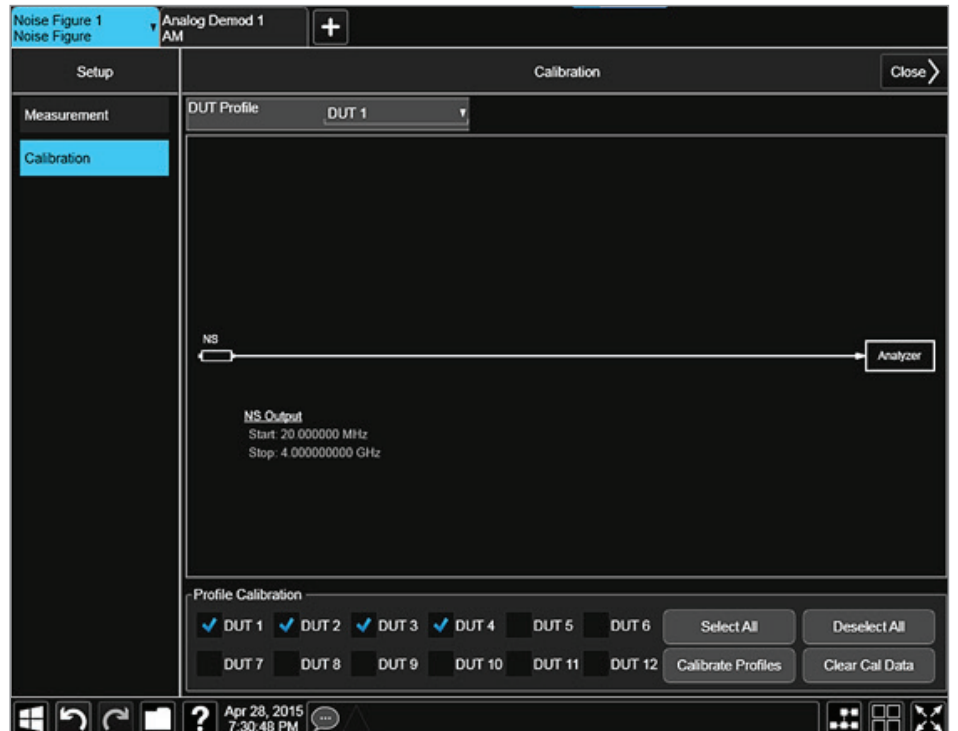
Noise figure and gain measurements for amplifier and converters

The N9069C noise figure measurement application provides accurate noise figure and gain results for the DUT, which can be amplifiers or converters (including multi-stage converters). The noise figure and gain results are shown versus frequencies.



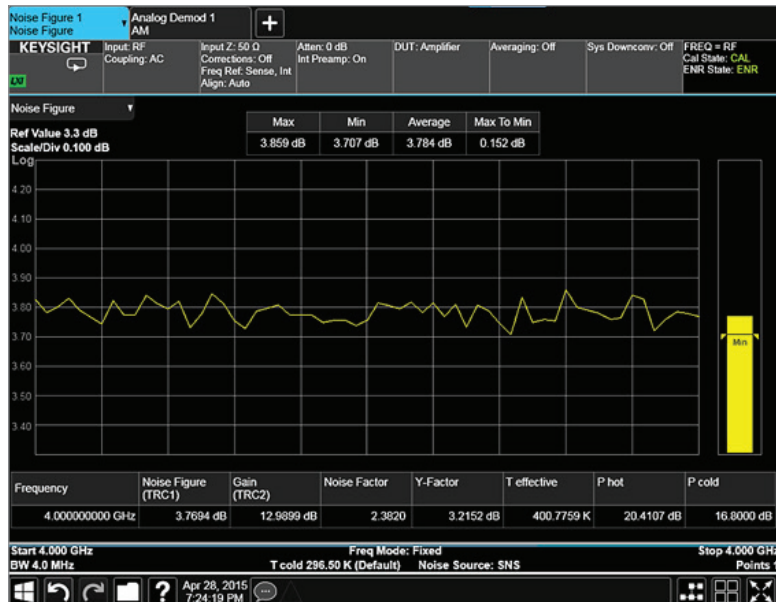
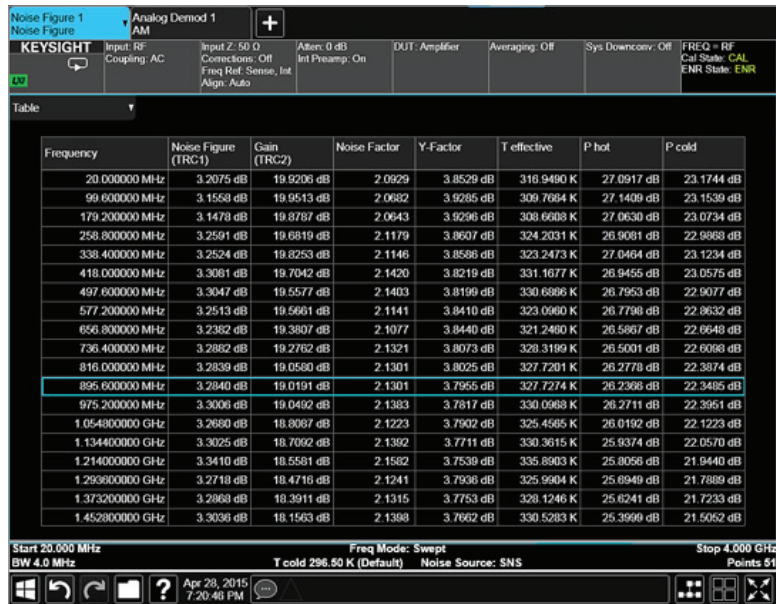
Multi-DUT calibration and measurement profiles

Use this feature to speed up your multi-DUT measurements. It enables you to set up measurement profiles for up to 12 DUTs, calibrate for each profile continuously, and make noise figure measurements on each DUT with the corresponding profile



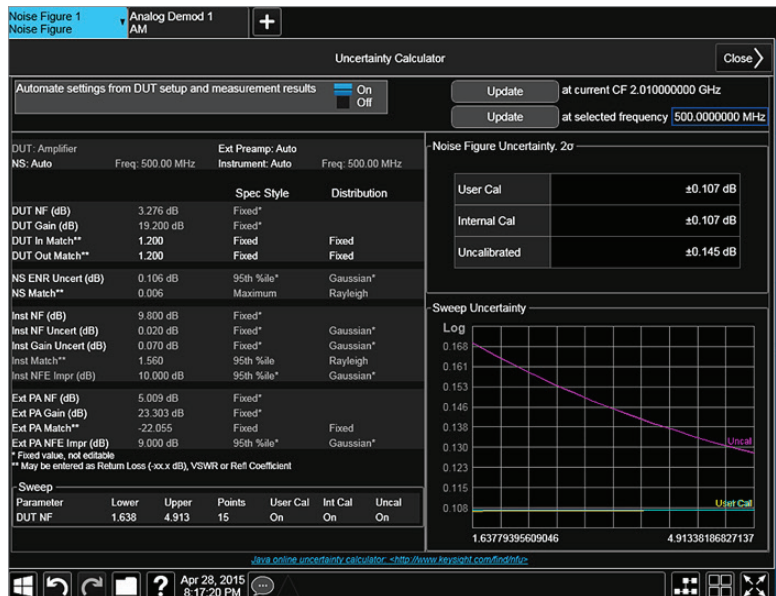
Simultaneous display of multi-results in table format and meter view

View multiple results of the DUT simultaneously in the table or meter layout. Results include noise figure, gain, noise factor, Y-Factor, T-Effective, P hot, and P cold.



Built-in uncertainty calculator

Use the built-in uncertainty calculator to calculate the measurement uncertainty for the current measurement. It simplifies the process of calculating measurement uncertainty by importing the SNS ENR and the USB preamplifier data (if connected to the analyzer) as well as the instrument data automatically.



Key Specifications

Definitions

- Specifications describe the performance of parameters covered by the product warranty.
- 95th percentile values indicate the breadth of the population (≈ 2) of performance tolerances expected to be met in 95% of cases with a 95% confidence. These values are not covered by the product warranty.
- Typical values are designated with the abbreviation "typ." These are performance beyond specification that 80% of the units exhibit with a 95% confidence. These values are not covered by the product warranty.
- Nominal values are designated with the abbreviation "nom." These values indicate expected performance, or describe product performance that is useful in the application of the product, but is not covered by the product warranty.

Analyzer noise figure is computed from the specified DANL. See specifications on following pages for further explanation.

Noise figure for the combination of USB preamp and analyzer is

$$NF_{sys} = 10 * \text{Log} (F_{preamp} + (F_{analyzer} - 1)/G_{preamp})$$

The noise figure and gain of the preamp are specified and warranted.

Analyzer VSWR is characterized to the 95th percentile but not measured and warranted. USB preamp VSWR is measured and warranted and becomes the input VSWR of the measurement system when used.

Instrument uncertainty is defined for gain measurements as uncertainty due to relative amplitude uncertainties encountered in the analyzer when making the measurements required for the gain computation.

The noise figure measurement application is not specified for use below 10 MHz. Instrument uncertainty will nominally be the same as the 10 MHz to 3.6 GHz specifications; however, performance is not warranted. Instrument uncertainty for gain is characterized to the 95th percentile above 3.6 GHz.

These notes apply to the following specifications. For more information on configuring an X-Series signal analyzer for noise figure measurements, depending on the DUT noise figure and gain, see the Noise Figure Measurement Guide, literature number N9069-90001.

Performance specifications

UXA with U7227A preamplifier

| Description | | Specifications | | | Supplemental information |
|--|-------------------|--------------------|---|-----------------------------|---|
| VSWR ¹ | Frequency | UXA full range | UXA 26.5 GHz + U7227A preamp full range | | |
| Band 0 | 10 to 100 MHz | 1.45 | 3.57 | | |
| Band 0 | 0.1 to 2 GHz | 1.45 | 1.54 | | |
| Band 0 | 2 to 3 GHz | 1.45 | 1.73 | | |
| Band 0 | 3 to 3.6 GHz | 1.45 | 1.93 | | |
| Band 1 | 3.5 to 4 GHz | 1.54 | 1.93 | | |
| Band 1 | 4 to 8.4 GHz | 1.54 | – | | |
| Band 2 | 8.3 to 13.6 GHz | 1.57 | – | | |
| Band 3 | 13.5 to 17.1 GHz | 1.48 | – | | |
| Band 4 | 17.0 to 26.5 GHz | 1.54 | – | | |
| Noise figure ^{2,3} | | Internal preamp on | Internal preamp off + U7227A | Internal preamp on + U7227A | |
| | 10 MHz to 100 MHz | 12.25 | 9.46 | 5.96 | |
| | 0.1 to 2.1 GHz | 12.25 | 9.49 | 5.45 | |
| | 2.1 to 3.6 GHz | 14.25 | 11.35 | 5.65 | |
| | 3.5 to 4.0 GHz | 14.25 | 12.88 | 5.63 | |
| | 4 to 6 GHz | 14.25 | – | – | |
| | 6 to 8.4 GHz | 14.25 | – | – | |
| | 8.3 to 13.6 GHz | 15.25 | – | – | |
| | 13.5 to 16.9 GHz | 17.25 | – | – | |
| | 16.9 to 18 GHz | 19.25 | – | – | |
| | 18 to 20 GHz | 19.25 | – | – | |
| | 20 to 26.5 GHz | 23.25 | – | – | |
| Instrument uncertainty for noise figure ⁴ | | | | | |
| 10 MHz to 26.5 GHz | | | | | |
| Noise source ENR | Measurement range | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.02 dB | ± 0.02 dB | ± 0.02 dB | |
| 12 to 17 dB | 0 to 30 dB | ± 0.025 dB | ± 0.025 dB | ± 0.025 dB | Using the internal preamp and RBW 4 ≤ MHz |
| 20 to 22 dB | 0 to 35 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| Instrument uncertainty for gain ^{5,6} | | | | | |
| | 10 MHz to 3.6 GHz | ± 0.07 dB | ± 0.07 dB | ± 0.07 dB | DUT gain range = |
| | > 3.6 GHz | ± 0.13 dB | ± 0.13 dB | ± 0.13 dB | –20 to +40 dB |
| Jitter | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | |

Performance specifications

UXA with U7227C preamplifier

| Description | | Specifications | | | Supplemental information |
|--|-------------------|--------------------|---|-----------------------------|---|
| VSWR ¹ | Frequency | UXA full range | UXA 26.5 GHz + U7227C preamp full range | | |
| Band 0 | 10 to 100 MHz | 1.45 | – | | |
| Band 0 | 0.1 to 3.6 GHz | 1.45 | 1.43 | | |
| Band 1 | 3.5 to 4 GHz | 1.54 | 1.43 | | |
| Band 1 | 4 to 8.4 GHz | 1.54 | 2.32 | | |
| Band 2 | 8.3 to 13.6 GHz | 1.57 | 2.32 | | |
| Band 3 | 13.5 to 17.1 GHz | 1.48 | 2.32 | | |
| Band 4 | 17.0 to 26.5 GHz | 1.54 | 2.32 | | |
| Noise figure ^{2,3} | | Internal preamp on | Internal preamp off + U7227A | Internal preamp on + U7227A | |
| | 10 MHz to 100 MHz | 12.25 | – | – | |
| | 0.1 to 2.1 GHz | 12.25 | 9.88 | 6.36 | |
| | 2.1 to 3.6 GHz | 14.25 | 11.60 | 6.52 | |
| | 3.5 to 4.0 GHz | 14.25 | 13.06 | 6.51 | |
| | 4 to 6 GHz | 14.25 | 11.64 | 5.56 | |
| | 6 to 8.4 GHz | 14.25 | 10.94 | 4.61 | |
| | 8.3 to 13.6 GHz | 15.25 | 10.66 | 4.57 | |
| | 13.5 to 16.9 GHz | 17.25 | 13.30 | 4.74 | |
| | 16.9 to 18 GHz | 19.25 | 15.77 | 5.06 | |
| | 18 to 20 GHz | 19.25 | 15.37 | 5.77 | |
| | 20 to 26.5 GHz | 23.25 | 20.39 | 6.25 | |
| Instrument uncertainty for noise figure ⁴ | | | | | |
| 10 MHz to 26.5 GHz | | | | | |
| Noise source ENR | Measurement range | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.02 dB | ± 0.02 dB | ± 0.02 dB | |
| 12 to 17 dB | 0 to 30 dB | ± 0.025 dB | ± 0.025 dB | ± 0.025 dB | Using the internal preamp and RBW 4 ≤ MHz |
| 20 to 22 dB | 0 to 35 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| Instrument uncertainty for gain ^{5,6} | | | | | |
| | 10 MHz to 3.6 GHz | ± 0.07 | ± 0.07 | ± 0.07 | DUT gain range = -20 to +40 dB |
| | > 3.6 GHz | ± 0.13 dB | ± 0.13 dB | ± 0.13 dB | |
| Jitter | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | |

Performance specifications

PXA with U7227A preamplifier

| Frequency | | PXA full range | PXA + U7227A full range | | |
|--|------------|--------------------|------------------------------|-----------------------------|---------------------------------------|
| VSWR ¹ | | | | | |
| Frequency | | | | | |
| 10 to 100 MHz | | 1.45 | 3.57 | | |
| 0.1 to 2 GHz | | 1.45 | 1.54 | | |
| 2 to 3 GHz | | 1.45 | 1.73 | | |
| 3 to 3.6 GHz | | 1.45 | 1.93 | | |
| 3.5 to 4 GHz | | 1.54 | 1.93 | | |
| 4 to 8.4 GHz | | 1.54 | – | | |
| 8.3 to 13.6 GHz | | 1.57 | – | | |
| 13.5 to 17.1 GHz | | 1.48 | – | | |
| 17.0 to 26.5 GHz | | 1.54 | – | | |
| | | Internal preamp on | Internal preamp off + U7227A | Internal preamp on + U7227A | Supplemental information |
| Noise figure ^{2,3} | | | | | |
| 10 to 100 MHz | | 12.25 | 9.46 | 5.96 | |
| 0.1 to 2.1 GHz | | 12.25 | 9.49 | 5.45 | |
| 2.1 to 3.6 GHz | | 14.25 | 11.35 | 5.56 | |
| 3.5 to 4 GHz | | 14.25 | 13.73 | 5.63 | |
| 4 to 6 GHz | | 14.25 | – | – | |
| 6 to 8.4 GHz | | 14.25 | – | – | |
| 8.3 to 13.6 GHz | | 15.25 | – | – | |
| 13.5 to 17.1 GHz | | 17.25 | – | – | |
| 16.9 to 18 GHz | | 19.25 | – | – | |
| 18 to 20 GHz | | 19.25 | – | – | |
| 20 to 26.5 GHz | | 23.25 | – | – | |
| Noise source ENR | | | | | |
| Measurement range | | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.02 dB | ± 0.02 dB | ± 0.02 dB | Using internal preamp and RBW ≤ 4 MHz |
| 12 to 17 dB | 0 to 30 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| 20 to 22 dB | 0 to 35 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| Jitter | | | | | |
| | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | |
| Instrument uncertainty for gain ^{4,5} | | | | | |
| 10 MHz to 3.6 GHz | | ± 0.13 dB | ± 0.13 dB | ± 0.13 dB | DUT gain range = –20 to +40 dB |
| > 3.6 GHz | | ± 0.13 dB | ± 0.13 dB | ± 0.13 dB | |

Instrument uncertainty for noise figure, 10 MHz to 26.5 GHz⁶

PXA with U7227C preamplifier

| Frequency | | PXA full range | PXA + U7227C full range | | |
|--|------------|--------------------|------------------------------|-----------------------------|---------------------------------------|
| VSWR ¹ | | | | | |
| Frequency | | | | | |
| 10 to 100 MHz | | 1.45 | – | | |
| 0.1 to 3.6 GHz | | 1.45 | 1.43 | | |
| 3.5 to 4 GHz | | 1.54 | 1.43 | | |
| 4 to 8.4 GHz | | 1.54 | 2.32 | | |
| 8.3 to 13.6 GHz | | 1.57 | 2.32 | | |
| 13.5 to 17.1 GHz | | 1.48 | 2.32 | | |
| 17.0 to 26.5 GHz | | 1.54 | 2.32 | | |
| | | Internal preamp on | Internal preamp off + U7227C | Internal preamp on + U7227C | Supplemental information |
| Noise figure ^{2,3} | | | | | |
| 10 to 100 MHz | | 12.25 | – | | |
| 0.1 to 2.1 GHz | | 12.25 | 9.88 | 6.36 | |
| 2.1 to 3.6 GHz | | 14.25 | 11.60 | 6.52 | |
| 3.5 to 4 GHz | | 14.25 | 13.88 | 6.51 | |
| 4 to 6 GHz | | 14.25 | 13.28 | 6.56 | |
| 6 to 8.4 GHz | | 14.25 | 12.61 | 4.61 | |
| 8.3 to 13.6 GHz | | 15.25 | 10.66 | 4.57 | |
| 13.5 to 16.9 GHz | | 17.25 | 13.30 | 4.74 | |
| 16.9 to 18 GHz | | 19.25 | 15.77 | 5.06 | |
| 18 to 20 GHz | | 19.25 | 15.37 | 5.77 | |
| 20 to 26.5 GHz | | 23.25 | 18.46 | 6.25 | |
| Noise source ENR | | | | | |
| Measurement range | | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.02 dB | ± 0.02 dB | ± 0.02 dB | Using internal preamp and RBW ≤ 4 MHz |
| 12 to 17 dB | 0 to 30 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| 20 to 22 dB | 0 to 35 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| Jitter | | | | | |
| | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | |
| Instrument uncertainty for gain ^{4,5} | | | | | |
| 10 MHz to 3.6 GHz | | ± 0.13 dB | ± 0.13 dB | ± 0.13 dB | DUT gain range = -20 to +40 dB |
| > 3.6 GHz | | ± 0.13 dB | ± 0.13 dB | ± 0.13 dB | |

Instrument uncertainty for noise figure, 10 MHz to 26.5 GHz⁶

PXA with U7227F preamplifier

| Frequency | PXA full range | PXA + U7227F full range | | |
|--|---------------------------|-------------------------------------|------------------------------------|---|
| VSWR ¹ | | | | |
| Frequency | | | | |
| 0.01 to 2 GHz | 1.39 | – | | |
| 2 to 3.6 GHz | 1.39 | 2.32 | | |
| 3.5 to 8.4 GHz | 1.50 | 2.32 | | |
| 8.3 to 13.6 GHz | 1.31 | 2.32 | | |
| 13.5 to 17.1 GHz | 1.33 | 2.32 | | |
| 17.0 to 26.5 GHz | 1.34 | 2.32 | | |
| 26.4 to 34.5 GHz | 1.41 | 2.32 | | |
| 34.4 to 40 GHz | 1.42 | 2.32 | | |
| 40 to 44 GHz | 1.42 | 3.00 | | |
| 44 to 50 GHz | 1.42 | 3.57 | | |
| | Internal preamp on | Internal preamp off + U7227F | Internal preamp on + U7227F | Supplemental information |
| Noise figure ^{2,3} | | | | |
| 10 to 100 MHz | 13.25 | – | – | |
| 2 to 2.1 GHz | 13.25 | 11.85 | 10.17 | |
| 2.1 to 3.6 GHz | 14.25 | 12.97 | 10.20 | |
| 3.5 to 4 GHz | 17.25 | 18.49 | 10.39 | |
| 4 to 8.4 GHz | 17.25 | 16.48 | 8.49 | |
| 8.3 to 13.6 GHz | 17.25 | 13.19 | 8.37 | |
| 13.5 to 17.1 GHz | 17.25 | 15.64 | 8.31 | |
| 17 to 20 GHz | 19.25 | 16.77 | 8.42 | |
| 20 to 26.5 GHz | 20.25 | 17.21 | 8.38 | |
| 26.4 to 30 GHz | 21.25 | 14.85 | 8.40 | |
| 30 to 34 GHz | 23.25 | 14.92 | 8.50 | |
| 33 to 37 GHz | 26.25 | 18.63 | 8.83 | |
| 37 to 40 GHz | 29.25 | 18.01 | 9.33 | |
| 40 to 43 GHz | 31.25 | 18.39 | 10.42 | |
| 43 to 44 GHz | 31.25 | 18.19 | 10.35 | |
| 44 to 46 GHz | 31.25 | 17.93 | 11.01 | Due to U7227F temperature instability, noise figure measurements are not traceable above 44 GHz with the preamp attached. |
| 46 to 50 GHz | 34.25 | 19.74 | 11.35 | |
| Noise source ENR | | | | |
| Measurement range | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.02 dB | ± 0.02 dB | Using internal preamp and RBW ≤ 4 MHz |
| 12 to 17 dB | 0 to 30 dB | ± 0.03 dB | ± 0.03 dB | |
| 20 to 22 dB | 0 to 35 dB | ± 0.03 dB | ± 0.03 dB | |
| Jitter | | | | |
| | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB |
| Instrument uncertainty for gain ^{4,5} | | | | |
| 10 MHz to 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | DUT gain range = -20 to +40 dB |
| > 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | |

Instrument uncertainty for noise figure, 10 MHz to 26.5 GHz⁶

MXA with U7227A preamplifier

| Frequency | | MXA full range | MXA + U7227A full range | | |
|--|------------|-----------------------|---------------------------------|--------------------------------|---------------------------------------|
| VSWR ¹ | | | | | |
| Frequency | | | | | |
| 10 to 100 MHz | | 1.52 | 3.57 | | |
| 0.1 to 2 GHz | | 1.52 | 1.43 | | |
| 2 to 3 GHz | | 1.52 | 1.73 | | |
| 3 to 3.6 GHz | | 1.52 | 1.93 | | |
| 3.5 to 4 GHz | | 1.68 | 1.93 | | |
| 4 to 8.4 GHz | | 1.68 | – | | |
| 8.3 to 13.6 GHz | | 1.69 | – | | |
| 13.5 to 17.1 GHz | | 1.66 | – | | |
| 17.0 to 26.5 GHz | | 1.66 | – | | |
| | | Internal preamp on | Internal preamp off + U7227A | Internal preamp on + U7227A | Supplemental information |
| Noise figure ^{2,3} | | | | | |
| 10 to 100 MHz | | 15.25 | 12.27 | 6.40 | |
| 0.1 to 2.1 GHz | | 15.25 | 10.59 | 5.65 | |
| 2.1 to 3.6 GHz | | 16.25 | 11.54 | 5.69 | |
| 3.5 to 4 GHz | | 16.25 | 11.38 | 5.66 | |
| 4 to 6 GHz | | 16.25 | – | – | |
| 6 to 8.4 GHz | | 16.25 | – | – | |
| 8.3 to 13.6 GHz | | 16.25 | – | – | |
| 13.5 to 17.1 GHz | | 19.25 | – | – | |
| 17 to 18 GHz | | 22.25 | – | – | |
| 18 to 20 GHz | | 22.25 | – | – | |
| 20 to 26.5 GHz | | 27.25 | – | – | |
| Noise source ENR | | | | | |
| Measurement range | | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.02 dB | ± 0.02 dB | ± 0.02 dB | Using internal preamp and RBW ≤ 4 MHz |
| 12 to 17 dB | 0 to 30 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| 20 to 22 dB | 0 to 35 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| Jitter | | | | | |
| | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | |
| Instrument uncertainty for gain ^{4,5} | | | | | |
| 10 MHz to 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | ± 0.19 dB | DUT gain range = -20 to +40 dB |
| > 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | ± 0.19 dB | |

Instrument uncertainty for noise figure, 10 MHz to 26.5 GHz⁶

MXA with U7227C preamplifier

| Frequency | | MXA full range | MXA + U7227C full range | | |
|---|------------|-----------------------|---------------------------------|--------------------------------|---------------------------------------|
| VSWR ¹ | | | | | |
| Frequency | | | | | |
| 10 to 100 MHz | | 1.52 | – | | |
| 0.1 to 3.6 GHz | | 1.52 | 1.43 | | |
| 3.5 to 4 GHz | | 1.68 | 1.43 | | |
| 4 to 8.4 GHz | | 1.68 | 2.32 | | |
| 8.3 to 13.6 GHz | | 1.69 | 2.32 | | |
| 13.5 to 17.1 GHz | | 1.66 | 2.32 | | |
| 17.0 to 26.5 GHz | | 1.66 | 2.32 | | |
| | | Internal preamp on | Internal preamp off + U7227C | Internal preamp on + U7227C | Supplemental information |
| Noise figure ^{2,3} | | | | | |
| 10 to 100 MHz | | 15.25 | – | | |
| 0.1 to 2.1 GHz | | 15.25 | 11.89 | 6.71 | |
| 2.1 to 3.6 GHz | | 16.25 | 13.14 | 6.81 | |
| 3.5 to 4 GHz | | 16.25 | 13.06 | 6.79 | |
| 4 to 6 GHz | | 16.25 | 12.45 | 5.87 | |
| 6 to 8.4 GHz | | 16.25 | 11.76 | 4.95 | |
| 8.3 to 13.6 GHz | | 16.25 | 11.47 | 4.71 | |
| 13.5 to 17.1 GHz | | 19.25 | 15.06 | 5.11 | |
| 17 to 18 GHz | | 22.25 | 15.77 | 5.92 | |
| 18 to 20 GHz | | 22.25 | 15.37 | 6.43 | |
| 20 to 26.5 GHz | | 27.25 | 21.36 | 7.65 | |
| Noise source ENR | | | | | |
| Measurement range | | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.02 dB | ± 0.02 dB | ± 0.02 dB | Using internal preamp and RBW ≤ 4 MHz |
| 12 to 17 dB | 0 to 30 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| 20 to 22 dB | 0 to 35 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| Jitter | | | | | |
| | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | |
| Instrument uncertainty for gain ^{4, 5} | | | | | |
| 10 MHz to 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | ± 0.19 dB | DUT gain range = -20 to +40 dB |
| > 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | ± 0.19 dB | |

Instrument uncertainty for noise figure, 10 MHz to 26.5 GHz⁶

EXA with U7227A preamplifier

| Frequency | | EXA full range | EXA + U7227A full range | | |
|--|------------|--------------------|------------------------------|-----------------------------|---------------------------------------|
| VSWR ¹ | | | | | |
| Frequency | | | | | |
| 10 to 100 MHz | | 1.52 | 3.57 | | |
| 0.1 to 2 GHz | | 1.52 | 1.54 | | |
| 2 to 3 GHz | | 1.52 | 1.73 | | |
| 3 to 3.6 GHz | | 1.52 | 1.93 | | |
| 3.5 to 4 GHz | | 1.68 | 1.93 | | |
| 4 to 8.4 GHz | | 1.68 | – | | |
| 8.3 to 13.6 GHz | | 1.69 | – | | |
| 13.5 to 17.1 GHz | | 1.66 | – | | |
| 17.0 to 26.5 GHz | | 1.66 | – | | |
| | | Internal preamp on | Internal preamp off + U7227A | Internal preamp on + U7227A | Supplemental information |
| Noise figure ^{2,3} | | | | | |
| 10 to 100 MHz | | 17.25 | 14.79 | 6.86 | |
| 100 MHz to 2.1 GHz | | 17.25 | 12.95 | 6.00 | |
| 2.1 to 3.6 GHz | | 18.25 | 13.17 | 6.05 | |
| 3.5 to 4 GHz | | 18.25 | 13.00 | 6.01 | |
| 4 to 6 GHz | | 18.25 | – | – | |
| 7 to 13.6 GHz | | 19.25 | – | – | |
| 13.5 to 17.1 GHz | | 21.25 | – | – | |
| 17 to 18 GHz | | 25.25 | – | – | |
| 18 to 20 GHz | | 25.25 | – | – | |
| 20 to 26.5 GHz | | 29.25 | – | – | |
| Noise source ENR | | | | | |
| Measurement range | | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.02 dB | ± 0.02 dB | ± 0.02 dB | Using internal preamp and RBW ≤ 4 MHz |
| 12 to 17 dB | 0 to 30 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| 20 to 22 dB | 0 to 35 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| Jitter | | | | | |
| | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | |
| Instrument uncertainty for gain ^{4,5} | | | | | |
| 10 MHz to 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | ± 0.19 dB | DUT gain range = –20 to +40 dB |
| > 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | ± 0.19 dB | |

Instrument uncertainty for noise figure, 10 MHz to 26.5 GHz⁶

EXA with U7227C preamplifier

| Frequency | | EXA full range | EXA + U7227C full range | | |
|--|------------|--------------------|------------------------------|-----------------------------|---------------------------------------|
| VSWR ¹ | | | | | |
| Frequency | | | | | |
| 10 to 100 MHz | | 1.52 | – | | |
| 0.1 to 3.6 GHz | | 1.52 | 1.43 | | |
| 3.5 to 4 GHz | | 1.68 | 1.43 | | |
| 4 to 8.4 GHz | | 1.68 | 2.32 | | |
| 8.3 to 13.6 GHz | | 1.69 | 2.32 | | |
| 13.5 to 17.1 GHz | | 1.66 | 2.32 | | |
| 17.0 to 26.5 GHz | | 1.66 | 2.32 | | |
| | | Internal preamp on | Internal preamp off + U7227C | Internal preamp on + U7227C | Supplemental information |
| Noise figure ^{2,3} | | | | | |
| 10 to 100 MHz | | 17.25 | – | | |
| 100 MHz to 2.1 GHz | | 17.25 | 14.30 | 7.08 | |
| 2.1 to 3.6 GHz | | 18.25 | 14.82 | 7.23 | |
| 3.5 to 4 GHz | | 18.25 | 14.73 | 7.20 | |
| 4 to 6 GHz | | 18.25 | 14.15 | 6.33 | |
| 6 to 7 GHz | | 18.25 | 13.81 | 5.53 | |
| 7 to 13.6 GHz | | 19.25 | 15.90 | 5.34 | |
| 13.5 to 17.1 GHz | | 21.25 | 21.78 | 5.66 | |
| 17 to 18 GHz | | 25.25 | 21.55 | 7.24 | |
| 18 to 20 GHz | | 25.25 | 21.06 | 7.51 | |
| 20 to 26.5 GHz | | 29.25 | 23.32 | 8.68 | |
| Noise source ENR | | | | | |
| Measurement range | | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.02 dB | ± 0.02 dB | ± 0.02 dB | Using internal preamp and RBW ≤ 4 MHz |
| 12 to 17 dB | 0 to 30 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| 20 to 22 dB | 0 to 35 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| Jitter | | | | | |
| | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | |
| Instrument uncertainty for gain ^{4,5} | | | | | |
| 10 MHz to 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | ± 0.19 dB | DUT gain range = -20 to +40 dB |
| > 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | ± 0.19 dB | |

Instrument uncertainty for noise figure, 10 MHz to 26.5 GHz⁶

EXA with U7227F preamplifier

| Frequency | | EXA full range | EXA + U7227F full range | | |
|--|------------|--------------------|------------------------------|-----------------------------|---------------------------------------|
| VSWR ¹ | | | | | |
| Frequency | | | | | |
| 0.01 to 2 GHz | | 1.52 | – | | |
| 2 to 3.6 GHz | | 1.52 | 2.32 | | |
| 3.5 to 8.4 GHz | | 1.68 | 2.32 | | |
| 8.3 to 13.6 GHz | | 1.69 | 2.32 | | |
| 13.5 to 17.1 GHz | | 1.66 | 2.32 | | |
| 17.0 to 26.5 GHz | | 1.66 | 2.32 | | |
| 26.5 to 40 GHz | | – | 2.32 | | |
| 40 to 44 GHz | | – | 3.00 | | |
| | | Internal preamp on | Internal preamp off + U7227F | Internal preamp on + U7227F | Supplemental information |
| Noise figure ^{2,3} | | | | | |
| 10 to 1.2 GHz | | 14.25 | – | – | |
| 1.2 to 2.1 GHz | | 15.25 | – | – | |
| 2 to 2.1 GHz | | 15.25 | 12.65 | 10.27 | |
| 2.1 to 3.6 GHz | | 16.25 | 13.49 | 10.32 | |
| 3.5 to 4 GHz | | 18.25 | 19.36 | 10.49 | |
| 4 to 7 GHz | | 18.25 | 15.91 | 8.65 | |
| 7 to 20 GHz | | 18.25 | 15.91 | 8.34 | |
| 20 to 26.5 GHz | | 20.25 | 17.21 | 8.38 | |
| 26.5 to 32 GHz | | 23.25 | 19.69 | 8.56 | |
| 32 to 34 GHz | | 23.25 | 19.27 | 8.50 | |
| 33.9 to 40 GHz | | 26.5 | 23.67 | 8.72 | |
| 40 to 44 GHz | | 30.25 | 22.81 | 10.11 | |
| Noise source ENR | | | | | |
| Measurement range | | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.02 dB | ± 0.02 dB | ± 0.02 dB | Using internal preamp and RBW ≤ 4 MHz |
| 12 to 17 dB | 0 to 30 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| 20 to 22 dB | 0 to 35 dB | ± 0.03 dB | ± 0.03 dB | ± 0.03 dB | |
| Jitter | | | | | |
| | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | |
| Instrument uncertainty for gain ^{4,5} | | | | | |
| 10 MHz to 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | ± 0.19 dB | DUT gain range = -20 to +40 dB |
| > 3.6 GHz | | ± 0.19 dB | ± 0.19 dB | ± 0.19 dB | |

Instrument uncertainty for noise figure, 10 MHz to 26.5 GHz⁶

CXA with U7227A preamplifier

| Frequency | | CXA full range | CXA + U7227A full range | | |
|--|------------|--------------------|------------------------------|-----------------------------|---------------------------------------|
| VSWR ¹ | | | | | |
| Frequency | | | | | |
| 10 to 100 MHz | | 3.0 | 3.57 | | |
| 0.1 to 2 GHz | | 3.0 | 1.54 | | |
| 2 to 3 GHz | | 3.0 | 1.73 | | |
| 3 to 4 GHz | | 3.0 | 1.93 | | |
| 4 to 7.5 GHz | | 3.0 | – | | |
| 7.5 to 26.5 GHz | | 2.5 | – | | |
| | | Internal preamp on | Internal preamp off + U7227A | Internal preamp on + U7227A | Supplemental information |
| Noise figure ^{2,3} | | | | | |
| 10 to 100 MHz | | 17.25 | 13.92 | 6.86 | |
| 0.1 to 1.5 GHz | | 17.25 | 16.80 | 6.06 | |
| 1.5 to 3 GHz | | 19.25 | 16.10 | 6.37 | |
| 3 to 4 GHz | | 19.25 | 15.64 | 6.24 | |
| 4 to 6 GHz | | 19.25 | – | – | |
| 6 to 7.5 GHz | | 22.25 | – | – | |
| 7.5 to 13.6 GHz | | 22.25 | – | – | |
| 13.6 to 18 GHz | | 24.25 | – | – | |
| 18 to 20 GHz | | 24.25 | – | – | |
| 20 to 24 GHz | | 27.25 | – | – | |
| 24 to 26.5 GHz | | 37.25 | – | – | |
| Noise source ENR | | | | | |
| Measurement range | | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.05 dB | ± 0.05 dB | ± 0.05 dB | Using internal preamp and RBW ≤ 4 MHz |
| 12 to 17 dB | 0 to 30 dB | ± 0.05 dB | ± 0.05 dB | ± 0.05 dB | |
| 20 to 22 dB | 0 to 35 dB | ± 0.1 dB | ± 0.1 dB | ± 0.1 dB | |
| Jitter | | | | | |
| | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | DUT gain range = –20 to +40 dB |
| Instrument uncertainty for gain ^{4,5} | | | | | |
| | | ± 0.20 dB | ± 0.20 dB | ± 0.20 dB | |

Instrument uncertainty for noise figure, 10 MHz to 26.5 GHz⁶

CXA with U7227C preamplifier

| Frequency | | CXA full range | CXA + U7227C full range | | |
|--|------------|--------------------|------------------------------|-----------------------------|---------------------------------------|
| VSWR ¹ | | | | | |
| Frequency | | | | | |
| 10 to 100 MHz | | 3.0 | – | | |
| 0.1 to 3 GHz | | 3.0 | 1.43 | | |
| 3 to 4 GHz | | 3.0 | 1.43 | | |
| 4 to 7.5 GHz | | 3.0 | 2.32 | | |
| 7.5 to 26.5 GHz | | 2.5 | 2.32 | | |
| | | Internal preamp on | Internal preamp off + U7227C | Internal preamp on + U7227C | Supplemental information |
| Noise figure ^{2,3} | | | | | |
| 10 to 100 MHz | | 17.25 | – | – | |
| 0.1 to 1.5 GHz | | 17.25 | 18.04 | 7.12 | |
| 1.5 to 3 GHz | | 19.25 | 17.67 | 7.55 | |
| 3 to 4 GHz | | 19.25 | 17.43 | 7.47 | |
| 4 to 6 GHz | | 19.25 | 16.88 | 6.62 | |
| 6 to 7.5 GHz | | 22.25 | 18.36 | 7.10 | |
| 7.5 to 13.6 GHz | | 22.25 | 18.76 | 6.36 | |
| 13.6 to 18 GHz | | 24.25 | 22.53 | 6.75 | |
| 18 to 20 GHz | | 24.25 | 22.04 | 7.10 | |
| 20 to 24 GHz | | 27.25 | 22.98 | 7.96 | |
| 24 to 26.5 GHz | | 37.25 | 32.27 | 14.75 | |
| Noise source ENR | | | | | |
| Measurement range | | | | | |
| 4 to 6.5 dB | 0 to 20 dB | ± 0.05 dB | ± 0.05 dB | ± 0.05 dB | Using internal preamp and RBW ≤ 4 MHz |
| 12 to 17 dB | 0 to 30 dB | ± 0.05 dB | ± 0.05 dB | ± 0.05 dB | |
| 20 to 22 dB | 0 to 35 dB | ± 0.1 dB | ± 0.1 dB | ± 0.1 dB | |
| Jitter | | | | | |
| | | ± 0.15 dB | ± 0.15 dB | ± 0.15 dB | DUT gain range = -20 to +40 dB |
| Instrument uncertainty for gain ^{4,5} | | | | | |
| | | ± 0.20 dB | ± 0.20 dB | ± 0.20 dB | |

Instrument uncertainty for noise figure, 10 MHz to 26.5 GHz⁶

1. Analyzer VSWR is characterized to the 95th percentile but not measured and warranted. The VSWR measurement is made on the PNA-X which is traceable. The reverse isolation of the USB preamp is high enough that the system VSWR is insignificantly affected by the analyzer VSWR. So the system VSWR is the warranted VSWR of the USB preamp.
2. Analyzer noise figure is computed from the specified DANL using $NF = D - (K - L + B)$ where D is the DANL (displayed average noise level), K is kTB (-173.98 dBm in a 1 Hz bandwidth at 290 K), L is 2.51 dB (the effect of log averaging used in DANL verifications), N is 0.24 dB (the ratio of the noise bandwidth of the RBW filter with which the DANL is specified to an ideal noise bandwidth), B is ten times the base-10 logarithm of the RBW (in hertz) in which the DANL is specified. B is 0 dB for the 1 Hz RBW. The actual NF will vary from the nominal due to frequency response errors. Frequency response errors help as often as they harm, so NF derived from the DANL is a very good approximation to the true NF. Any other uncertainties created by deriving the noise figure are small second-order uncertainties the GUM does not require.
3. Noise figure for the combination of USB preamp and analyzer is $NF_{sys} = 10 \cdot \text{Log}(F_{preamp} + (F_{analyzer} - 1)/G_{preamp})$. The noise figure and gain of the preamp are specified and warranted. The noise figure of the analyzer is derived and discussed in [2]. The uncertainty due to the noise figure of the analyzer is smaller than [2].
4. "Instrument Uncertainty" is defined for noise figure analysis as uncertainty due to relative amplitude uncertainties encountered in the analyzer when making the measurements required for a noise figure computation. The relative amplitude uncertainty depends on, but is not identical to, the relative display scale fidelity, also known as incremental log fidelity. The uncertainty of the analyzer is multiplied within the computation by an amount that depends on the Y factor to give the total uncertainty of the noise figure or gain measurement. See Agilent App Note 57-2, literature number 5952-3706E for details on the use of this specification. Jitter (amplitude variations) will also affect the accuracy of results. The standard deviation of the measured result decreases by a factor of the square root of the Resolution Bandwidth used and by the square root of the number of averages. This application uses the 4 MHz Resolution Bandwidth as default because this is the widest bandwidth with uncompromised accuracy.
5. "Instrument Uncertainty" is defined for gain measurements as uncertainty due to relative amplitude uncertainties encountered in the analyzer when making the measurements required for the gain computation. See Agilent App Note 57-2, literature number 5952-3706E for details on the use of this specification. Jitter (amplitude variations) will also affect the accuracy of results. The standard deviation of the measured result decreases by a factor of the square root of the Resolution Bandwidth used and by the square root of the number of averages. This application uses the 4 MHz Resolution Bandwidth as default since this is the widest bandwidth with uncompromised accuracy.
6. Instrument uncertainty for gain is characterized to the 95th percentile above 3.6 GHz.

Note: Data subject to change

For a complete list of specifications, refer to the appropriate specifications guide:

- UXA: www.keysight.com/find/uxa_specifications
- PXA: www.keysight.com/find/pxa_specifications
- MXA: www.keysight.com/find/mxa_specifications
- EXA: www.keysight.com/find/exa_specifications
- CXA: www.keysight.com/find/cxa_specifications
- NFA: www.keysight.com/find/NFA_X-Series_specifications

Computing measurement uncertainty

Keysight provides three versions of noise figure uncertainty calculation, including

- Built-in noise figure uncertainty calculator (NFUC) enables you to calculate measurement uncertainty directly using the current measurement results.
- Spreadsheet version gives you the most freedom to enter DUT information and instrument specifications to get an accurate noise figure uncertainty. The spreadsheet version of the NFUC can be found at: www.keysight.com/find/nfu
- Online version enables you to sweep on almost all the relevant parameters to see their impact on measurement uncertainty. Access the online version of the NFUC through: www.keysight.com/find/nfuc

Software Licensing and Instrument Configuration

Choose from two license types::

- **Fixed, perpetual license:**
This allows you to run the application in the X-Series analyzer in which it is initially installed.
- **Transportable, perpetual license:**
This allows you to run the application in the X-Series analyzer in which it is initially installed, plus it may be transferred from one multi-touch X-Series analyzer to another.

You Can Upgrade!

Options can be added after your initial purchase.

All of our X-Series application options are license-key up-gradable.



N9069C noise figure X-Series measurement application

| Model-Option | Description, license type |
|--------------|--|
| N9069C-3FP | Noise figure measurement fixed perpetual |
| N9069C-3TP | Noise figure measurement transportable perpetual |

Hardware Configuration

For optimizing noise figure measurements with noise figure measurement application, Keysight recommends a minimum level of X-Series multi-touch signal analyzer hardware functionality at each instrument performance point.

Supported analyzers include:

- UXA N9040B
- PXA N9030B
- MXA N9020B
- EXA N9010B
- CXA N9000B

| Capability | Instrument Option | Benefit |
|-----------------------|--------------------------|--|
| Electronic Attenuator | -EA3 | Recommended: Fast and reliable attenuation changes ideal for manufacturing without the wear associated with mechanical attenuators up to 3.6 GHz in 1 dB steps |
| Pre-amplifier | 3.6 GHz (-P03) or higher | Required: For maximizing the measurement sensitivity to meet specifications |

The following NFA X-Series Noise Figure Analyzers are supported:

- N8973B
- N8974B
- N8975B
- N8976B

The NFA-X-Series comes standard with the fine step attenuator, precision frequency reference, full band preamplifier, noise floor extension, and U7227 USB preamplifier so no additional options are required.

Noise source

346 Series noise sources work with the full range of Keysight noise figure solutions. They are categorized by frequency coverage as well as excess noise ratio (ENR). The SNS noise sources replicate the ENR output and frequency coverage of the 346 Series noise sources, however with the SNS Series, ENR data is stored in an EPROM and is automatically downloaded to the instrument, eliminating the need to manually enter the values into the calibration table at each cardinal frequency point. In addition, a thermistor is built into the sensor to continually update the analyzer with the correct temperature, delivering automatic temperature compensation/correction within the measurement's source.

The U7227A/C/F USB preamplifiers, used with an X-Series signal analyzer reduces uncertainty of Y-factor noise figure measurements up to 50 GHz.

| Noise source | Frequency range | ENR |
|--------------|--------------------|---------------|
| 346A | 10 MHz to 18 GHz | 5 to 7 dB |
| 346B | 10 MHz to 18 GHz | 14 to 16 dB |
| 346C | 10 MHz to 26 GHz | 12 to 17 dB |
| 346CK01 | 1 GHz to 50 GHz | 7 to 20 dB |
| 346CK40 | 1 GHz to 40 GHz | 3 to 14 dB |
| Q347B | 33 GHz to 50 GHz | 6 to 13 dB |
| R347B | 26.5 GHz to 40 GHz | 10 to 13 dB |
| N4000A | 10 MHz to 18 GHz | 4.6 to 6.5 dB |
| N4001A | 10 MHz to 18 GHz | 14 to 16 dB |
| N4002A | 10 MHz to 26 GHz | 12 to 17 dB |

Note: If the DUT noise figure is beyond 30 dB, then the Keysight PNA-X Option 029 for noise figure measurements on a network analyzer may be more suitable than the Y-factor method.

USB preamplifiers

| Specification | U7227A | U7227C | U7227F |
|---|--|---|--|
| Frequency | 10 MHz to 4 GHz | 100 MHz to 26.5 GHz | 2 GHz to 50 GHz |
| Gain (dB) | 10 to 100 MHz: > 16 100 MHz to 4 GHz: > 0.5F + 17 | 100 MHz to 26.5 GHz: > 16.1 + 0.26F | 2 to 50 GHz: > 16.5 + 0.23F |
| Input return loss (Input SWR) | 10 to 100 MHz: > 5 dB (3.57) 100 MHz to 2 GHz: > 13.5 dB (1.54) 2 to 3 GHz: > 11.5 dB (1.73) 3 to 4 GHz: > 10 dB (1.93) | 100 MHz to 4 GHz: > 15 dB (1.43) 4 to 26.5 GHz: > 8 dB (2.32) | 2 GHz to 40 GHz: > 8 dB (2.32) 40 to 44 GHz: > 6 dB (3.00) 44 to 50 GHz: > 5 dB (3.57) |
| Output return loss (Output SWR) | 10 MHz to 4 GHz: > 18 dB (1.29) | 100 MHz to 4 GHz: > 18 dB (1.29) 4 to 26.5 GHz: > 11 dB (1.78) | 2 GHz to 4 GHz: > 18 dB (1.29) 4 to 40 GHz: > 11 dB (1.78) 40 to 50 GHz: > 8 dB (2.32) |
| Noise figure | 10 to 100 MHz: < 5.5 dB 10 MHz to 4 GHz: < 5 dB | 100 MHz to 4 GHz: < 6 dB 4 to 6 GHz: < 5 dB 6 to 18 GHz: < 4 dB 18 to 26.5 GHz: < 5 dB | 2 to 4 GHz: < 10 dB 4 to 40 GHz: < 8 dB 40 to 44 GHz: < 9 dB 44 to 50 GHz: < 10 dB |
| Plug and play USB connection | Yes | Yes | Yes |
| Optimized gain slope for better spectrum analysis | Yes | Yes | Yes |
| Automatic gain compensation | Yes | Yes | Yes |
| Automatic temperature compensation | Yes | Yes | Yes |

Additional Information

Measurement, user's and programming guides can be found on the product Web page in the document library: www.keysight.com/find/n9069c

Literature

Fundamentals of RF and Microwave Noise Figure Measurements - Application Note, literature number 5952-8255EN

Noise Figure Measurement Accuracy - the Y-factor method - Application Note, literature number 5952-3706EN

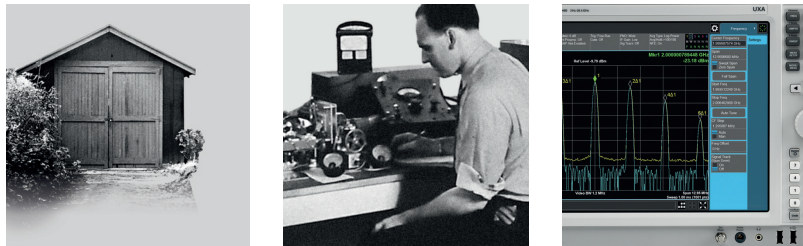
10 Hints for Making Successful Noise Figure Measurements - Application Note, literature number 5980-0288E

Keysight N4000A, N4001A, N4002A SNS Series Noise Sources 10 MHz to 26.5 GHz - Technical Overview, literature number 5980-0288E

Keysight USB Preamplifiers U7227A/C/F - Technical Overview, literature number 5991-4246EN

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