Microwave & Millimeter Wave

Noise Figure Measurement Solutions

CETC China Electronics Technology Instrument Co., Ltd

Contents

Ceyear

1. Ceyear Introduction

2017

| Headquarters	Qingdao, China
Establishment	1968 (CETC 41)
Business Focus	Instrument & Components, ATS
Employees	4,000 (1,500 R&D Engineers)

Ceyear

2. 1 Ceyear Profile - Headquarters

Qingdao Headquarter

1. Old R&D Building
2. National Key Lab，
   Metrology Center
3. New Innovation Building
4. New Employee Apartment
5. Precision Machining Center
6. Manufacturing Center
7. Hotel and Training Center

Microwave Components, Instruments and Systems R&D and Manufacturing Campus
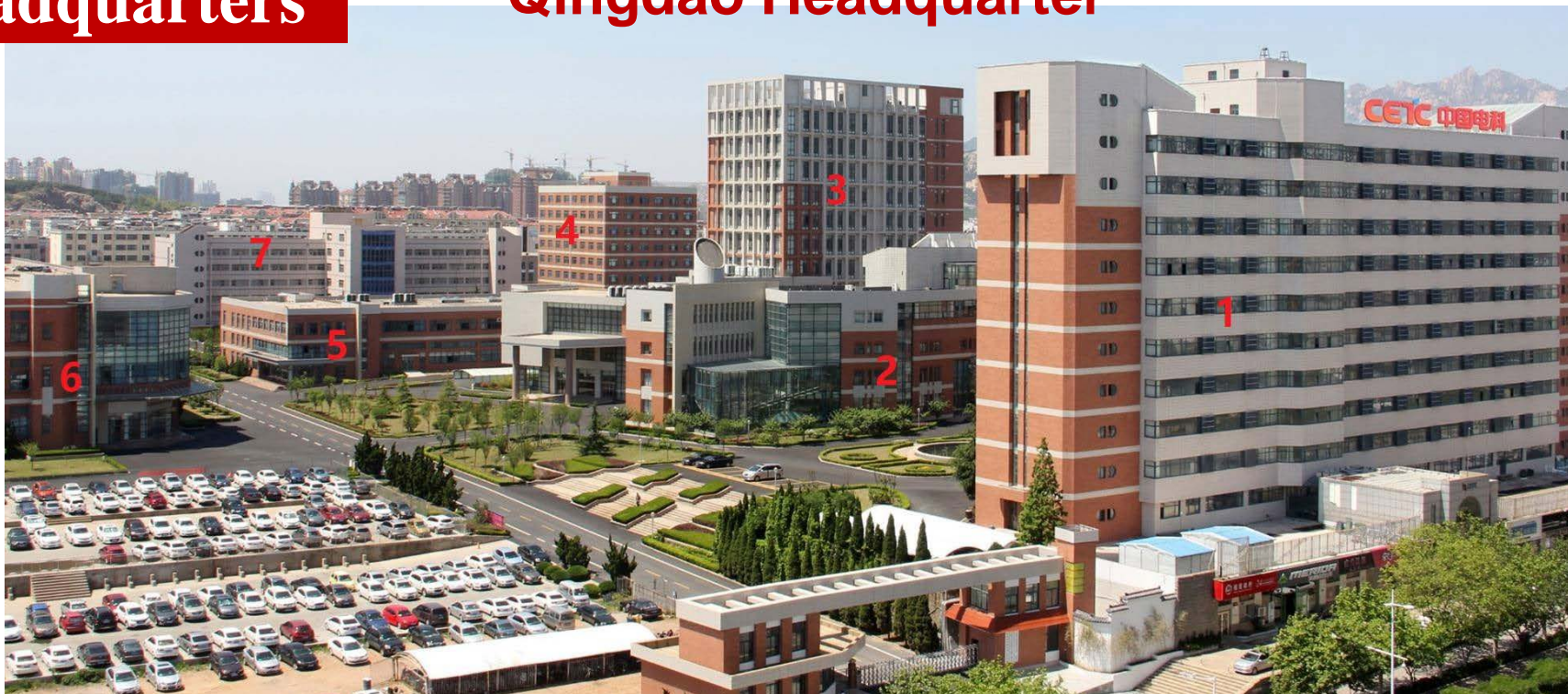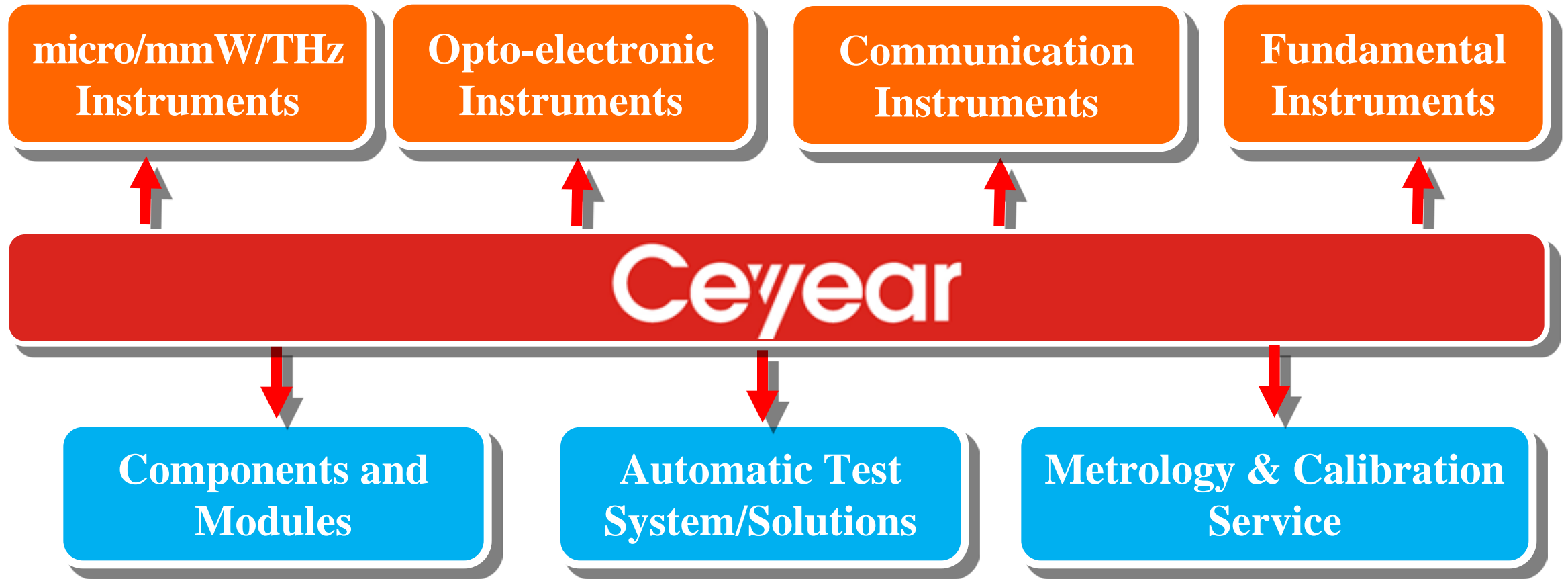
2. 2 Ceyear Profile - Bengbu Branch

Bengbu R&D Center

● Ceyear is derived from two professional institutes – the 40th and 41st institute of CETC.

● Two R&D centers focusing on optical instruments and connectors, switches, cables.

3. Business Range

4. Typical Instruments and Solutions

Instruments & Components

Signal Generator

Vector Network Analyzer

Noise Figure Analyzer

Spectrum/ Signal Analyzer

Handheld Spectrum Analyzer

Digital Storage Oscilloscope

Fusion Splicer

System Integration/ Total Solution

5. Ceyear Certificates and Laboratories
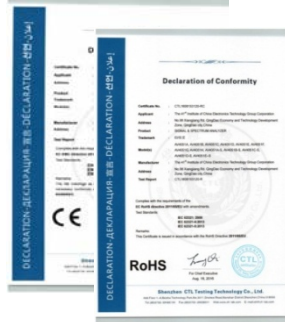

ISO 9001

ISO 14001

OHSA 18001

ISO/IEC 17025 = CNAS-CL01

CE and RoHS

Внесение в госреестр

Certificates

National Key Laboratory for Science and Technology on Electronic Test & Measurement

National Defense Optical and Electronic Primary Metrology Laboratory

Beidou Open Laboratory Qingdao Sub Laboratory

National Quality Supervision & Test Center for Electronic Instrument，Connectors and Relays

National-level Labs, R&D centers, regulation commissions and centers are put in Ceyear for operation and administration purpose.

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Contents

Ceyear

1 Why do we need Noise Figure?

$$\mathrm{NF} = 10\log_{10}(F) = 10\log_{10}\left(\frac{\mathrm{SNR_i}}{\mathrm{SNR_o}}\right) = \mathrm{SNR_{i,\ dB}} - \mathrm{SNR_{o,\ dB}}$$

Noise Figure is defined as the **degradation of signal-to-noise ratio** between the input and output. It is a dB value that defines the amount of noise that a device/circuit/system adds to the signal that passes through it. The smaller, the better. It is one of the key specification to quantify the ability to process very weak signals. It's widely used to characterize the features of amplifier, mixer, up/down frequency converter, receiving channel and even an entire receiver system.
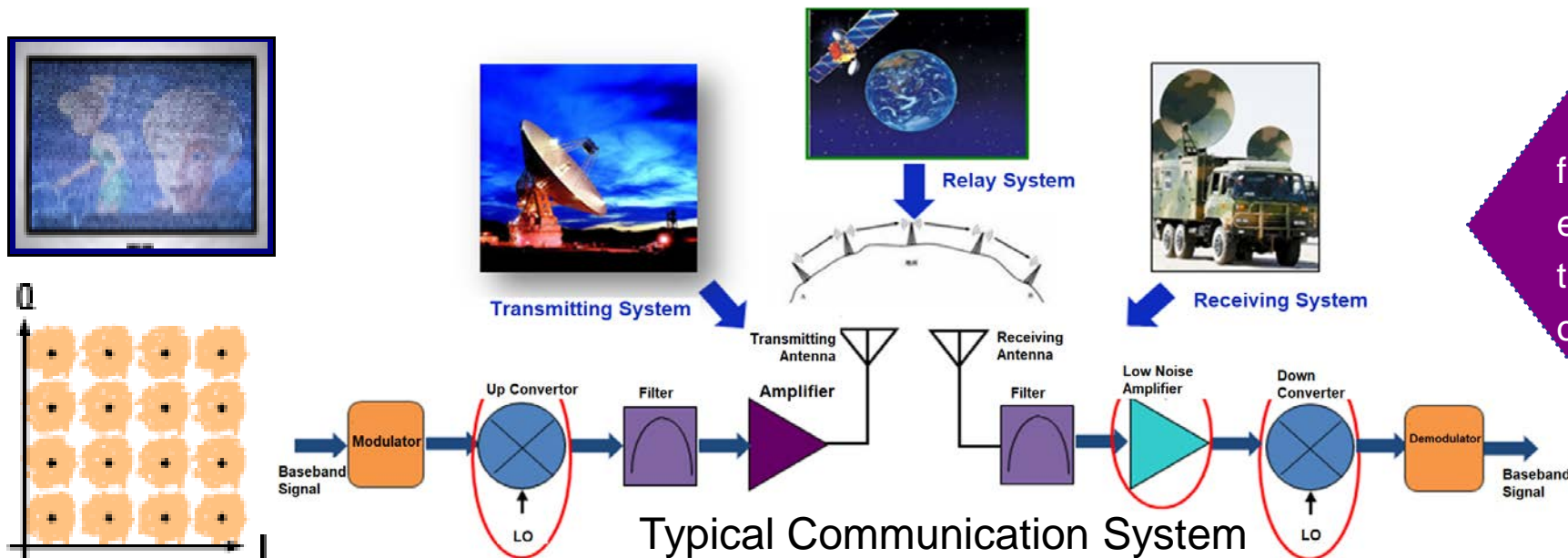
The optimization of noise figure from 2dB to 1dB for a receiver equals to an increase of 26% transmitting power, or an increase of 40% antenna diameter.

Relay System

Transmitting System

Receiving System

Transmitting Antenna

Receiving Antenna

Low Noise Amplifier

Down Converter

Up Convertor

Filter

Amplifier

Filter

Modulator

Demodulator

Baseband Signal

Baseband Signal

LO

LO

Typical Communication System

2.1 Two FN Measurement Theories

A. Y Factor (Hot-Cold Source)

This method makes use of a calibrated broadband noise source that contains two temperature states:

A high temperature state, T(ON source) with a higher output of noise power, and a low temperature state, T(OFF source) with reduced noise output. The noise source is applied to the input of the device under test (DUT)and the noise power at the output of the DUT is measured for each of the two input noise states. The noise figure and gain of the DUT are calculated from these measurements.

This method is suitable for **Spectrum Analyzer** with NF option and dedicated **Noise Figure Analyzer**

$$F = \frac{SNR_{in}}{SNR_{out}} \quad (1)$$

$\Longrightarrow$

$$N_a = kT_0 B G_1 \left(\frac{ENR}{Y-1} - 1 \right)$$

$$ENR = \frac{T_{hot} - T_{cold}}{290K}$$

2.2 Two FN Measurement Theories

B. Cold Source

The other method is the cold-source or direct-noise method.. E-cal can change the source match around 50 Ω. Using the noise power and vector error model under different impedances, the method can calculate the accurate Noise Figure under 50 Ω.

This method is suitable for **Vector Network Analyzer** with NF option.

➢ Provide mismatch correction algorithm
➢ S-parameters data can reduce noise figure uncertainty
➢ Requires a tuner and analysis software
➢ Measurement system can be complex and expensive

DUT

Slope=known amplifier gain

P_{out}

P_{in}

Noise generated by Amplifier

Cold Source Method
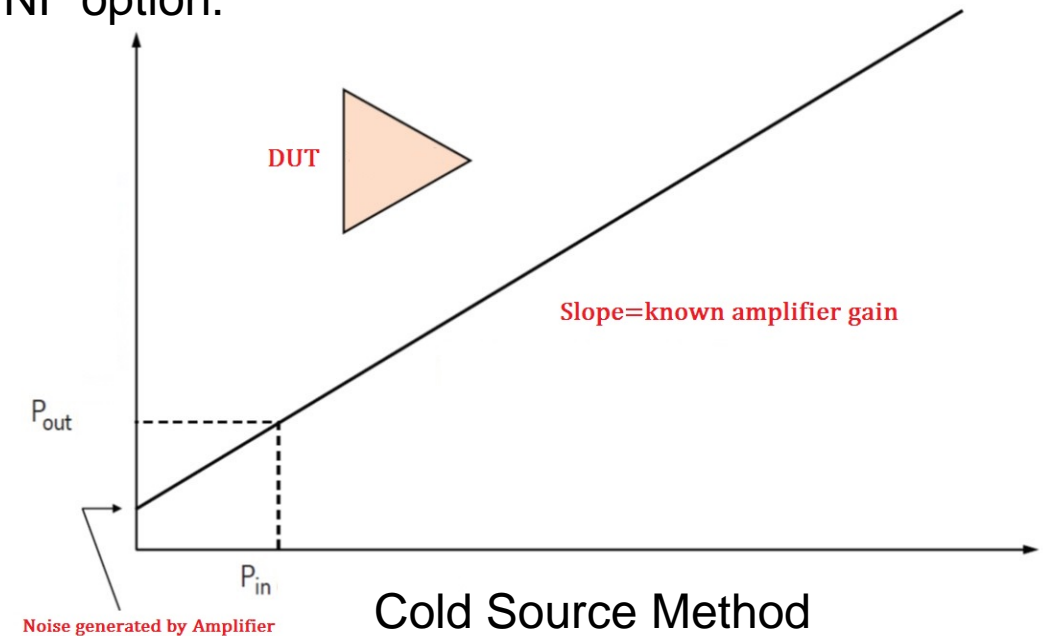
2.3 Two NF Method Comparison

Features

◆ **Y-factor method**

● The most common method and most cost-efficient solution
● When the Noise Source can be connected to the DUT and the ENR is low, this method can provide high and acceptable accuracy
● The noise source is needed during calibration and measurement process

◆ **Cold-source method**

● Work with high performance VNA, can provide S parameter, compression and NF at the same time

● Have the highest measurement accuracy.

● Need VNA, E-cal and Noise Source. The most costly solution.

● The noise source is needed during calibration process
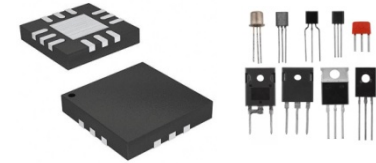
Low Noise Ics
Amplifier, Transistor, T/R

Mixers and Up/ Down Converter

Signal Receiver Chain

Contents

1. Ceyear NF Measurement Solutions

Noise Figure Measurement System can automatically measure the NF of linear or quasi-linear network. It can perform many functions, such as calibration process, error correction and uncertainty calculation.
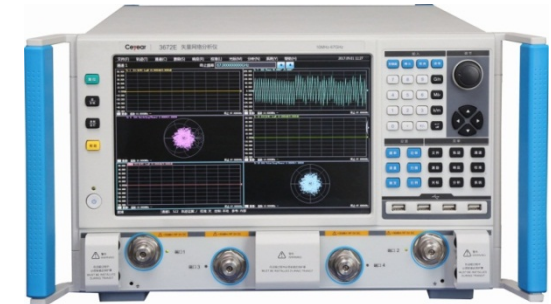
Three ways to measure NF
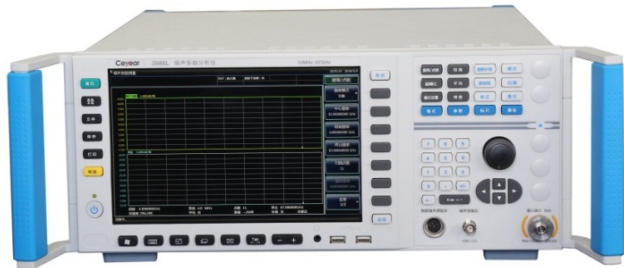
**Noise Figure Analyzer
(Dedicated Instrument)**
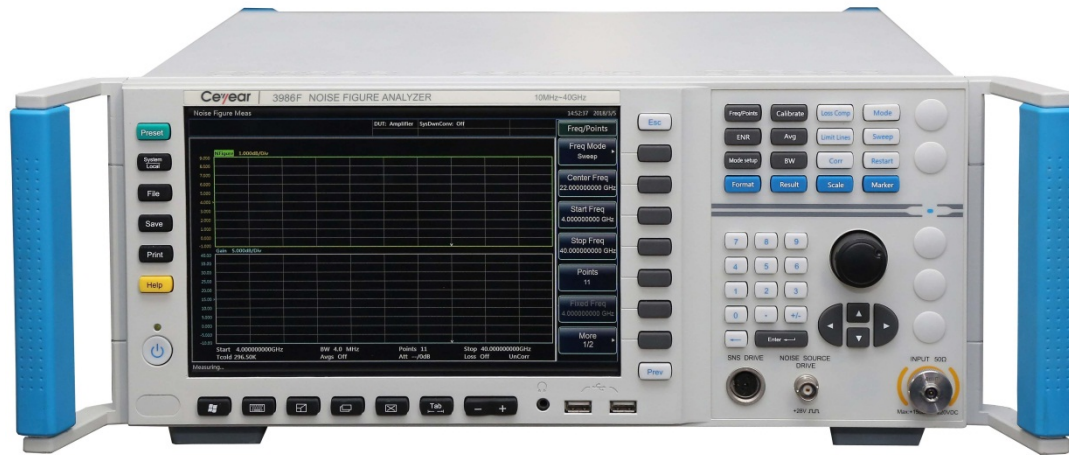
**Spectrum Analyzer
(with NF option)**

**Vector Network Analyzer
(with NF option)**

Together with different kind of **Noise Sources** or **Electronic-Calibration kits (E-Cal)**.
For sub-Teraherts application, frequency extender receiving modules are also needed.

2.1 3986 series Noise Figure Analyzer

The Dedicated NF Measurement Instrument

3986 series NF Analyzer
Coaxial 10 MHz~67 GHz, Extendable to 110 GHz

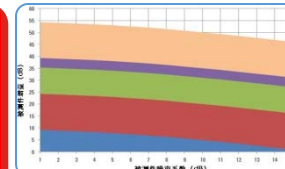**16603 series Standard**
Noise Source

16604 series Smart
Noise Source

- 10MHz to 67GHz to 110GHz
- Amplifier/ Upconverter/ Downconverter Measurement Mode
- Standard/Smart Noise Source
- Loss Compensation, Uncertainty Calculator, Limitation Functions
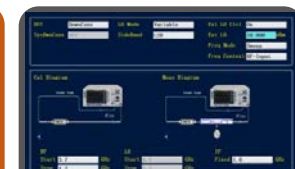- Features very low internal self Noise Figure with standard pre-amplifier

Wide Freq. Range

High Performance

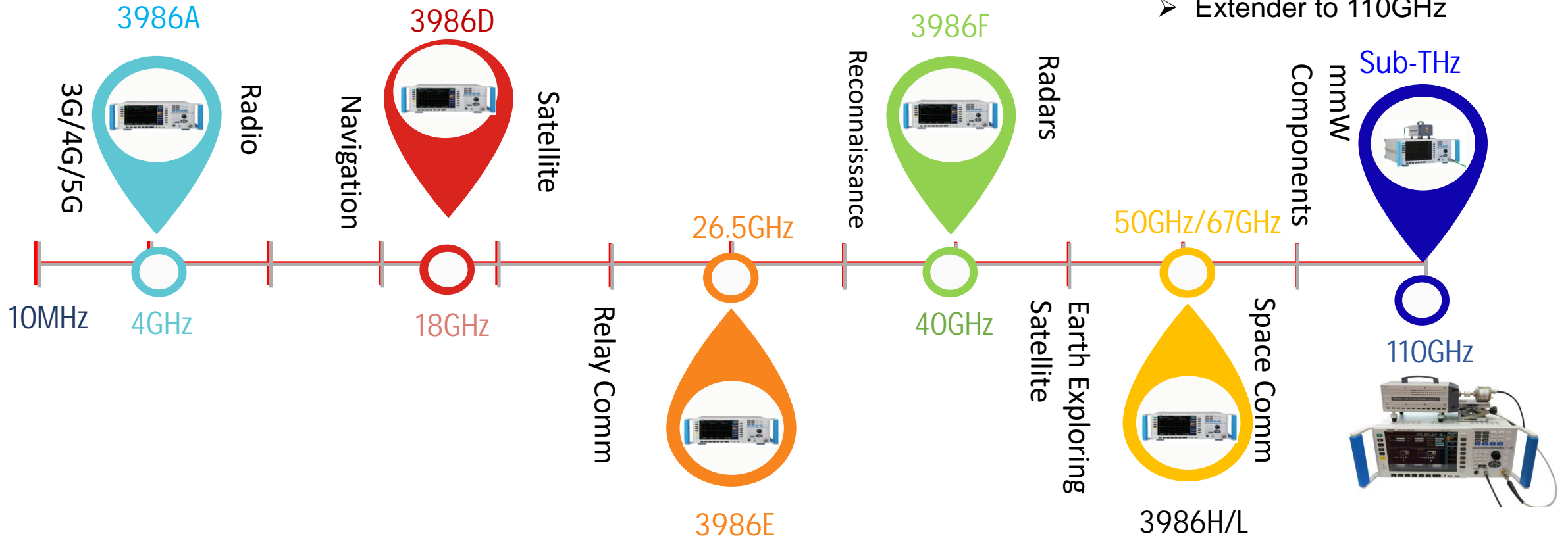**Multiple Function**

Easy to Operate

https://youtu.be/SjraPa416uE

2.2 3986 series Noise Figure Analyzer

Full Banded series NF Measurement Solution

- 3986A: 10MHz~4GHz
- 3986D: 10MHz~18GHz
- 3986E: 10MHz~26.5GHz
- 3986F: 10MHz~40GHz
- 3986H: 10MHz~50GHz
- 3986L: 10MHz~67GHz
- Extender to 110GHz

3986A

3986D

3986F

Sub-THz

3G/4G/5G

Radio

Navigation

Satellite

Reconnaissance

Radars

mmW Components

26.5GHz

50GHz/67GHz

10MHz

4GHz

18GHz

Relay Comm

40GHz

Earth Exploring Satellite

Space Comm

110GHz

3986E

3986H/L

2.3 3986 series Noise Figure Analyzer

High Sensitivity, Accuracy and Reliability

High Sensitivity

Sensitivity is Better than -165 dBm/Hz from 10MHz to 50GHz. Best Sensitivity can be -170dBm/Hz

To solve NF measurement for ultra-low noise components, circuits and system in new radar/5G applications.

High Accuracy

NF Range：0～35dB Measurement Uncertainty: 0.1dB

To solve accurate NF measurement featuring large NF range in transmitter and travelling-wave tube.
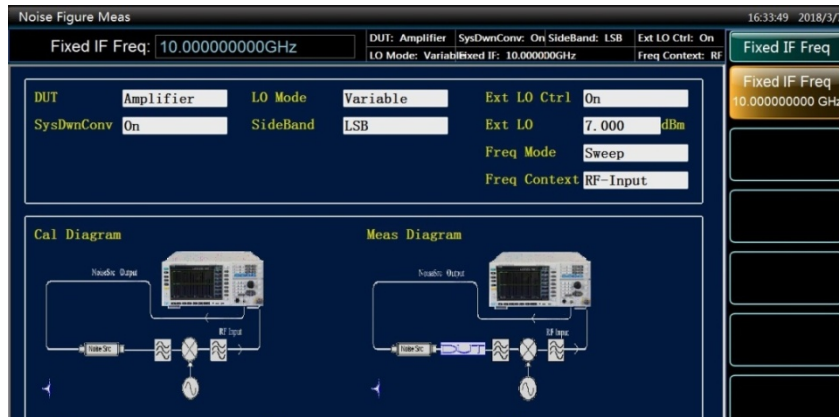
High Reliability

Endure input power: +25dBm
Endure induced 50Hz/220V or 60Hz/110V AC impulse

Port protective circuits can guarantees a very high reliability to meet the demands from radar and communication systems for high gain IC or device.

2.3 3986 series Noise Figure Analyzer

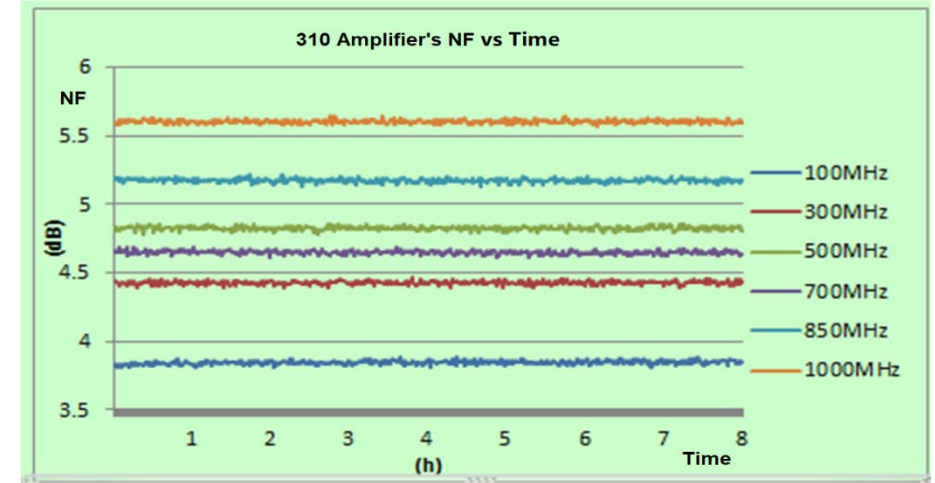## Multiple Functions, High Stability

- Simple Configuration;
- Easy operation;
- Auto test of multi-stage frequency converting chain;
- Auto uncertainty calculation;
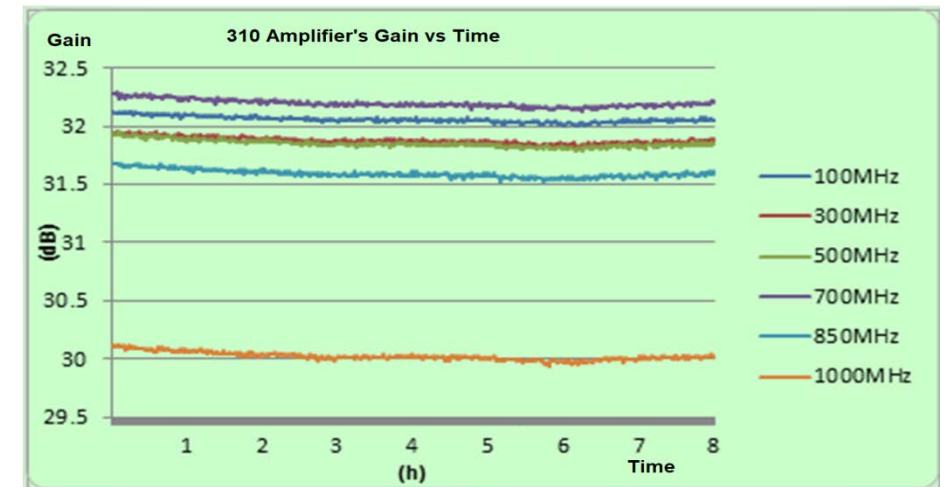- Gain compensation before or after DUT.

- Noise power spectral density analysis
- Multiple expressions using table or curves
- Built-in uncertainty calculator

NF and Gain changing within 8 hours
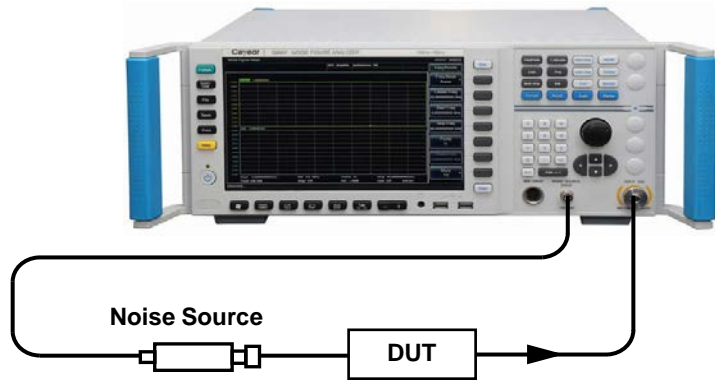

Noise Figure drift < 0.1dB

Gain drift < 0.2dB within 8 hours .

Http://www.ceyear.com

2.4 3986 series Noise Figure Analyzer

Multiple Functions

A. NF and Gain measurement for Linear components and systems

B. NF and Gain measurement for Amplifier with higher frequency

C. NF and Gain measurement for Up/Down Converter and Receiver Front-end Channel

A. Basic Amplifier Mode
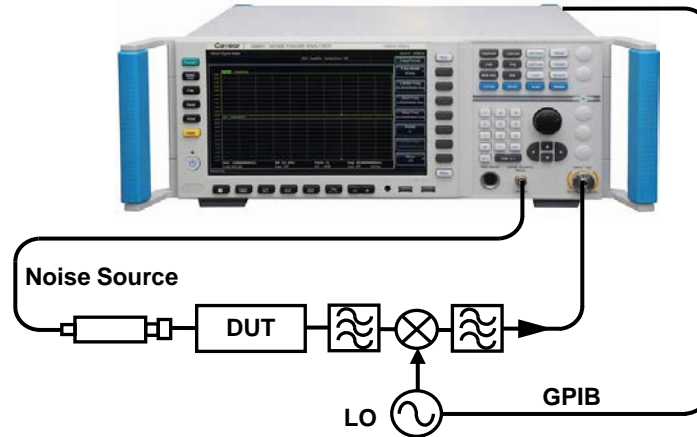
B. System Down Converter Mode

C. Up/down converter measurement

For common amplifier NF and Gain measurements.

When the amplifier's frequency is larger than the NF's, an external mixer can be configured to down-convert the frequency.
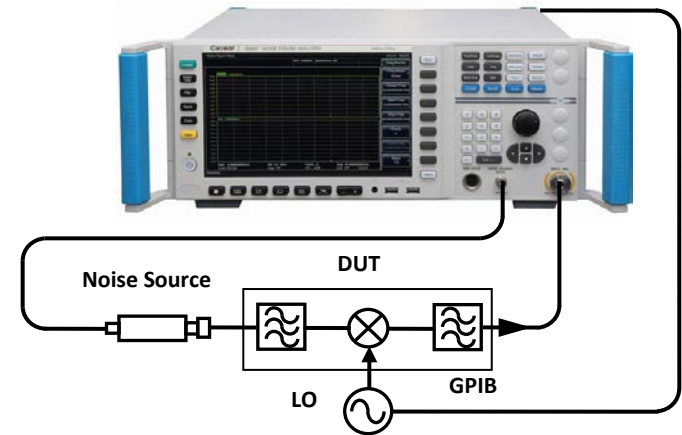
When the DUT is up/down converter, such as mixer, transmitter/ receiver, you can control an external LO through GPIB to make the measurement

2.5 3986 series Noise Figure Analyzer

3986 series NF Analyzer Configuration Selection

Model	Frequency	NF Range	NF Measurement Uncertainty	Ports
3986A	10MHz ~ 4GHz	0 ~ 30dB	±0.05dB	Input: 3.5mm(m) Noise Source: Standard BNC or Smart Multi-cords
		0 ~ 35dB	±0.10dB	
3986D	10MHz ~ 18GHz	0 ~ 30dB	±0.10dB	
		0 ~ 35dB	±0.15dB	
3986E	10MHz ~ 26.5GHz	0 ~ 30dB	±0.10dB	
		0 ~ 35dB	±0.15dB	
3986F	10MHz ~ 40GHz	0 ~ 30dB	±0.10dB	Input: 2.4mm(m) Noise Source: Standard BNC or Smart Multi-cords
		0 ~ 35dB	±0.15dB	
3986H	10MHz ~ 50GHz	0 ~ 30dB	±0.10dB	
		0 ~ 35dB	±0.15dB	

2.6 3986 series Noise Figure Analyzer

16603/4 series Noise Source Selection

Noise Source Model	Frequency	ENR	Output	Types
16603DA	10MHz ~ 18GHz	（5～8）dB	3.5mm(Male)	Standard BNC
16603DB	10MHz ~ 18GHz	(14～17) dB		
16603EB	10MHz ~ 26.5GHz	(12～17) dB		
16603FB	10MHz ~ 40GHz	(12～19) dB	2.4mm(Male)	
16603HB	10MHz ~ 50GHz	(10～19) dB		
16603LB	10MHz ~ 67GHz	(6~21) dB	1.85mm (male)	
16604DA	10MHz ~ 18GHz	（5～8）dB	3.5mm(Male)	Smart
16604DB	10MHz ~ 18GHz	(14～17) dB		
16604EB	10MHz ~ 26.5GHz	(12～17) dB		
16604FB	10MHz ~ 40GHz	(12～19) dB	2.4mm(Male)	
16604HB	10MHz ~ 50GHz	(10～19) dB		
16604LB	10MHz ~ 67GHz	(6~21) dB	1.85mm (male)	

2.7 3986 series Noise Figure Analyzer

NF Measurement Frequency Extension to 110GHz

Ceyear 3986 Series Noise Figure Analyzer

- 10MHz ~ 50GHz Frequency Coverage
- Standard pre-amplifier configuration.
- Amplifier/Upconverter/Downconverter Measurement Mode, Support Standard/Smart Noise Source
- NFA features ultra low inherent noise figure and very low uncertainty.

82411 H/K
(5mm)

82411 L/N/P
(3mm)

Ceyear 82411 Series Noise Figure Extender Module

- 50GHz ~ 110 GHz Seamless Coverage
- Low SWR
- High Sensitivity and Performance

To test mm-W amplifier and Up/down Converter's Noise Figure and Gain up to 110GHz.

2.8 3986 series Noise Figure Analyzer

NF Measurement Frequency Extender Modules

Ceyear 82411series Frequency Extender Modules Specifications

Specifications	82411H	82411K	82411L	82411N	82411P
Frequency Range (GHz)	50~63.5	61.5~75	75~88.5	86.5~100	96.5~110
Input SWR	< 1.7:1	< 1.7:1	< 1.8:1	< 1.8:1	< 1.8:1
Inherent NF (dB)	< 16	< 16	< 10	< 10	< 10
IF Output Range (GHz)	4.5~18	4.5~18	4.5~18	4.5~18	4.5~18
Channel Conversion Gain (dB)	> 5	> 5	> 5	> 5	> 5
Image Rejection (dB)	> 30	> 30	> 30	> 30	> 30

* Only support Ceyear 3986 series Noise Figure Analyzer.

2.9 3986 series Noise Figure Analyzer

Typical 110GHz NF Measurement Configuration

System Features:

- Very low inherent instrument noise figure;
- Industry leading sensitivity and accuracy;
- Automatic calculation of measurement uncertainty;
- Three measurement mode with better flexibility.

Ceyear 110GHz Noise Figure Analysis System Configuration

	Module and Name	Brand	Unit	Remarks
1	3986 D/E/F/H/L Noise Figure Analyzer	Ceyear	1	Main unit with frequency more than 18GHz
2	82411 series Extender Modules	Ceyear	1 set	Banded Modules to extend up to 110GHz. WR15/WR10
3	NC5115 or NC5110 Noise Source	Noisecom	1	50GHz to 75GHz , WR15; 75GHz to 110GHz, WR10

3.1 NF Option based on Spectrum Analyzer

Ceyear 4051 series Spectrum/Signal Analyzer

3Hz to 4/ 9/ 13.2/ 18/ 26.5/ 40/ 45/ 50/ 67GHz

- 3Hz to 67GHz, to 750GHz
- Abundant measurement functions
- 550MHz analysis bandwidth
- Powerful spectrum signal analysis ability

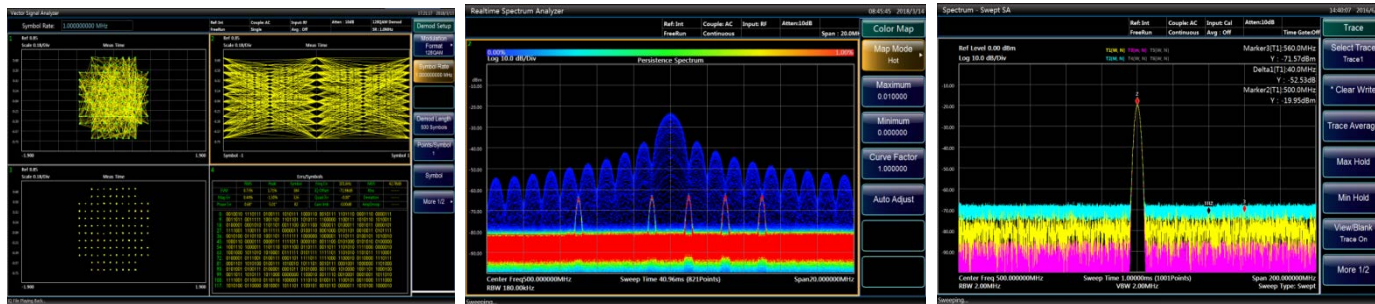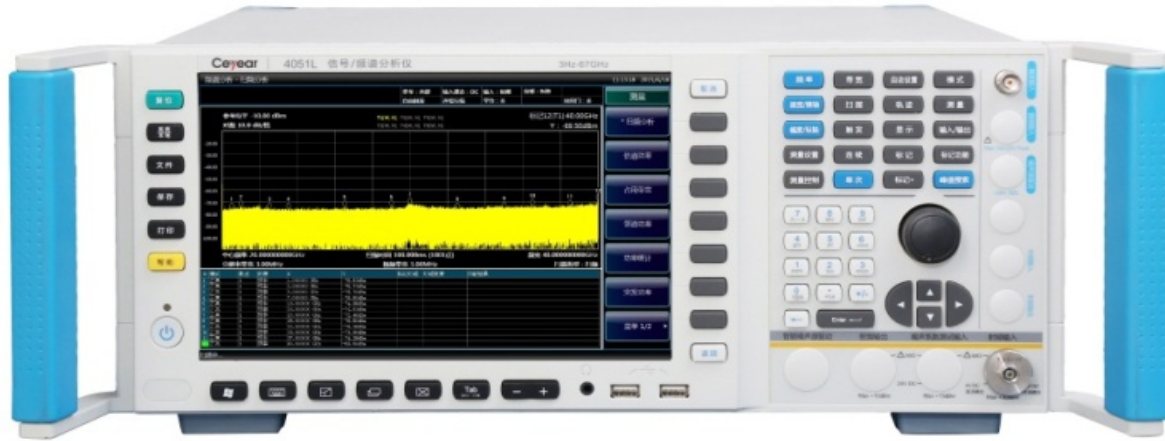| Wide Freq. Range | High Performance | Multiple Functions | High Reliability |

YouTube

https://youtu.be/y7gyaG3-v40

Http://www.ceyear.com

3.2 NF Option based on Spectrum Analyzer

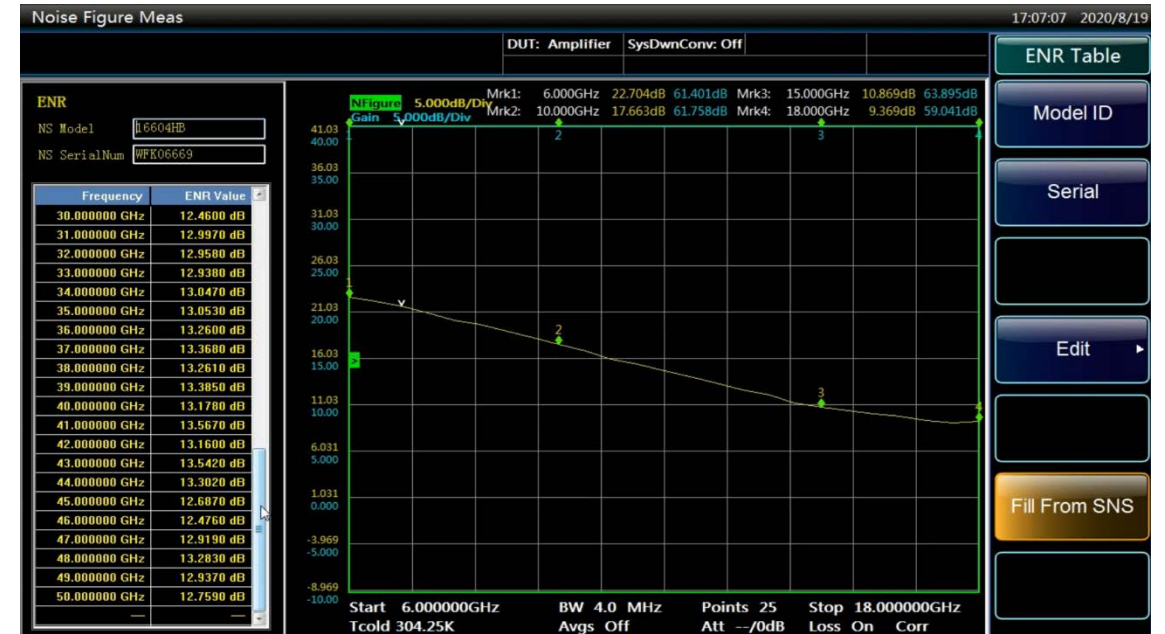**Ceyear 4051 series Spectrum/Signal Analyzer**

4051 series spectrum/Signal Analyzer
(H34: Pre LNA + H48: NF Option)
+
16603/4 series Noise Source

16603/16604 series noise source

Automatic Import ENR Data

Have the same operation and screen with 3986 series NFA!

3.3 NF Option based on Spectrum Analyzer

Features

- Up to 50GHz NF measurement;

- Comprehensive noise factor measurement functions for gain, Y-factor, effective temperature, etc.

- Up to 50GHz NF measurement;

- Comprehensive noise factor measurement functions for gain, Y-factor, effective temperature, etc.

- With optional internal preamplifier on the SA

- Works with Ceyear 16604 series smart noise sources and 16603 series traditional BNC-powered noise sources

- Measurement uncertainty calculator help you quickly get the uncertainty value
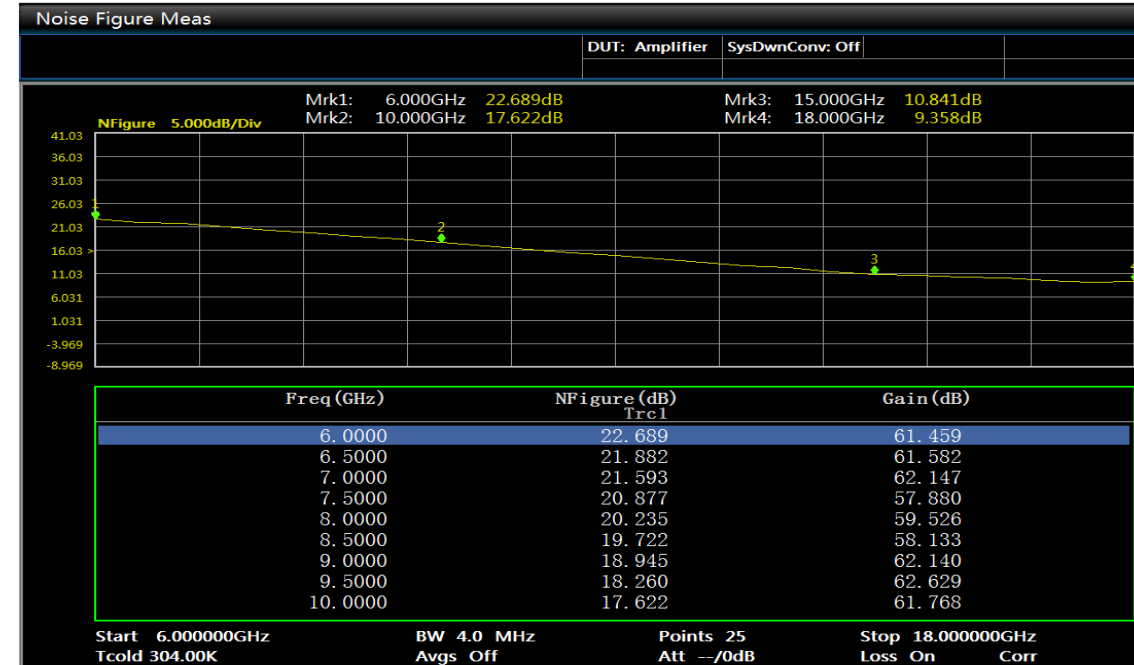
Noise Figure & Gain Test Result

Have the same operation and screen with 3986 series NFA!

4.1 NF Measurement based on VNA

Ceyear 3672 series Vector Network Analyzer

- ➢ Wide Freq. :10 MHz~67GHz, extendable to 750GHz
- ➢ Outstanding Dynamic Range and Test Speed
- ➢ Highly Integrated & Configurable
- ➢ Multiple Functions with many options, Extendable features
- ➢ High Repeatability, Reliability & Stability
- ➢ Complete test configuration for different Auto Test Systems

Ceyear 3672 VNA (2 or 4 ports)

**3672 series VNA
And 364X Frequency
Extender Modules**

4.2 NF Measurement based on VNA

How to measure NF using a VNA - 1

➤ Frequency from 10MHz to 50GHz

➤ Provide Scalar and Vector methods

➤ Support S parameters, Noise Figures and Noise Parameters measurement in a single connection

➤ Support different calibration methods

Setup NF Measurement Configuration

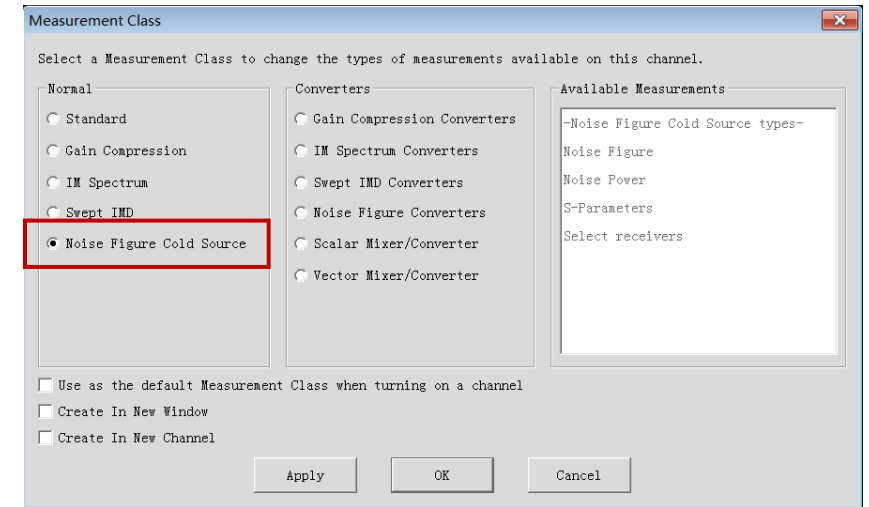**3672 series VNA**
(003: NF Option)
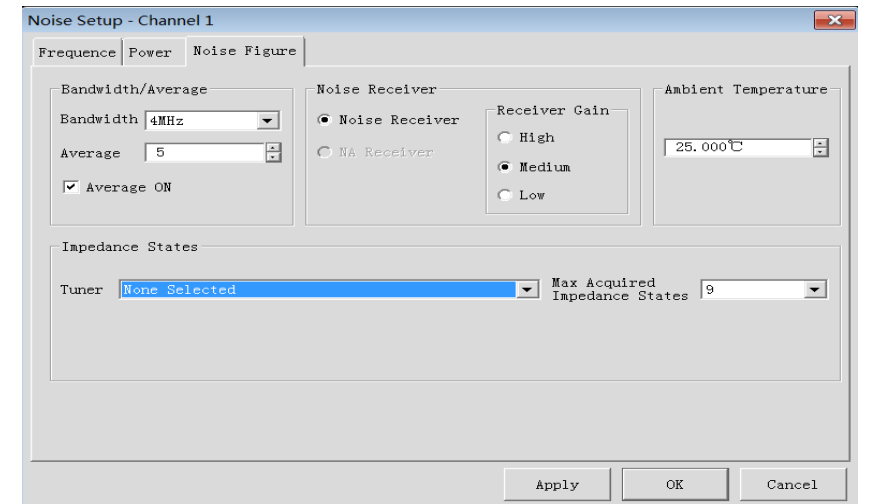**+**
2040X series E-cal
+
16603 series NS

E-cal   **Noise Source**
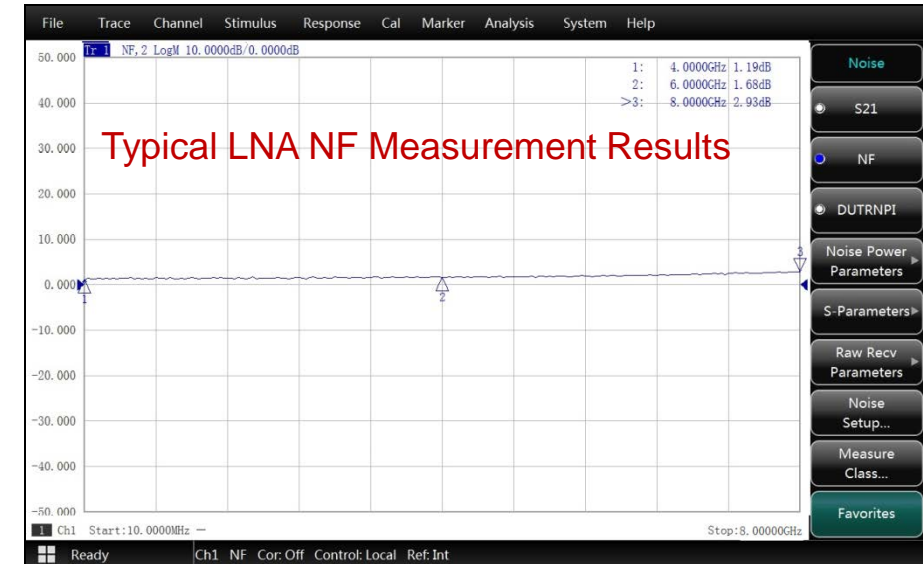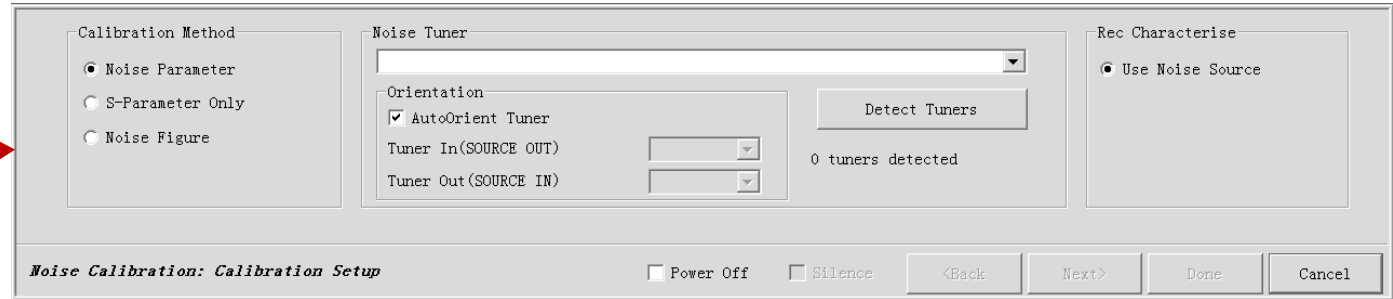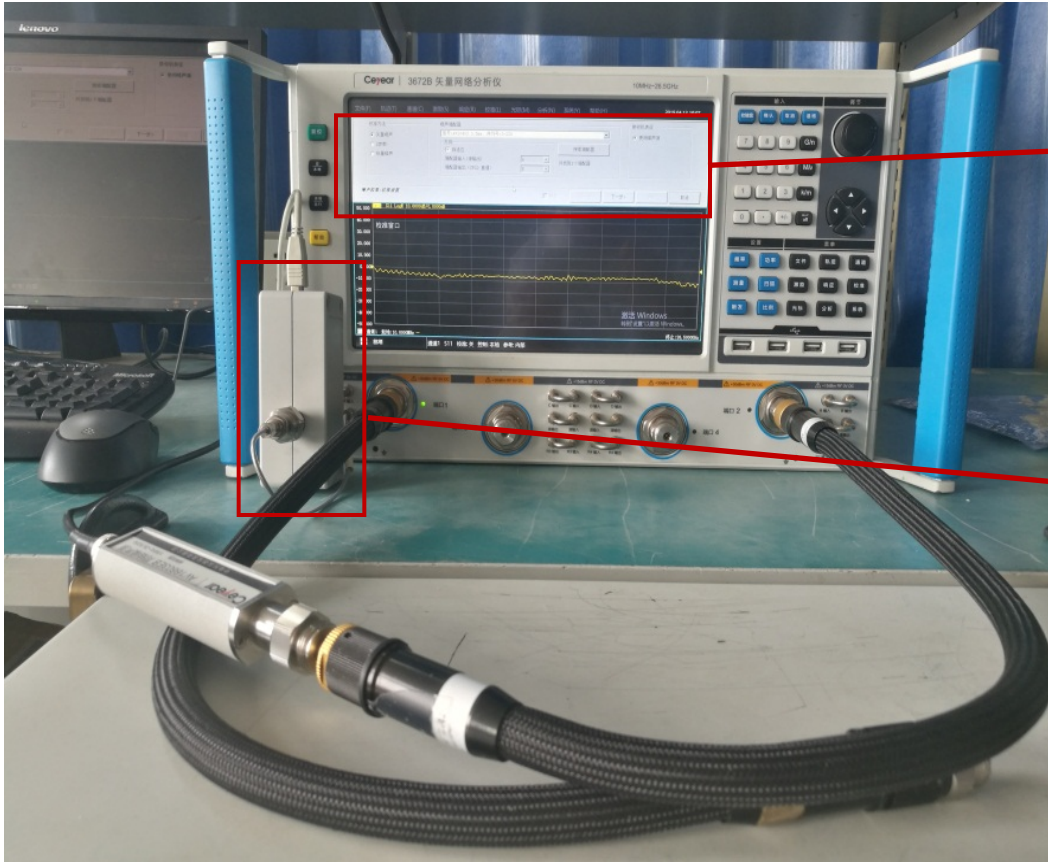

Step 1: Select Noise Figure Measurement

Step 2: Setup NF Measurement Configuration

4.3 NF Measurement based on VNA

How to measure NF using a VNA - 3

Step 3: Calibration methods selection and setups

E-Cal

Typical LNA NF Measurement Results
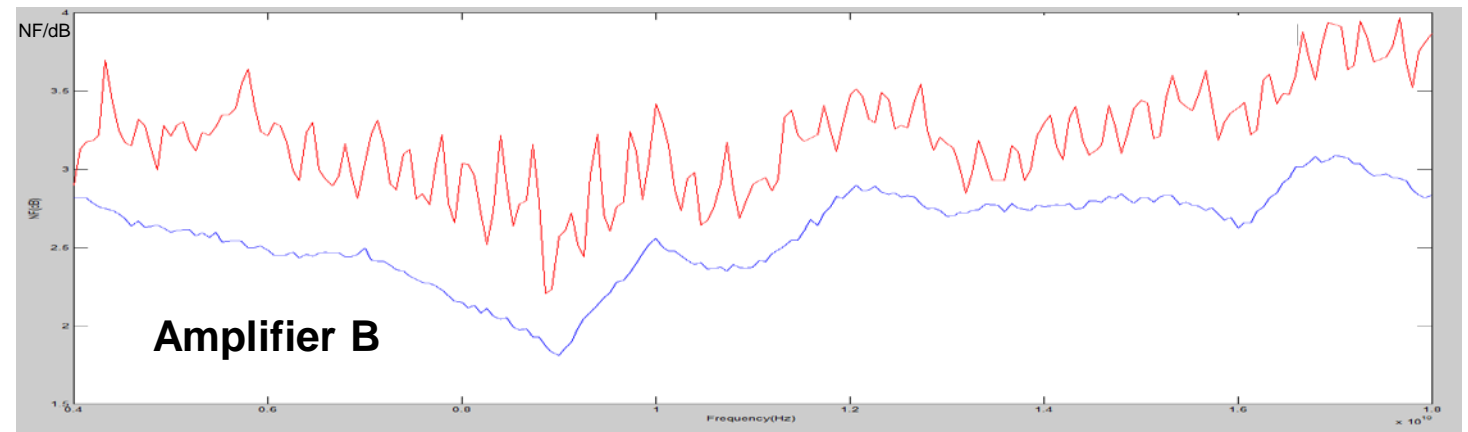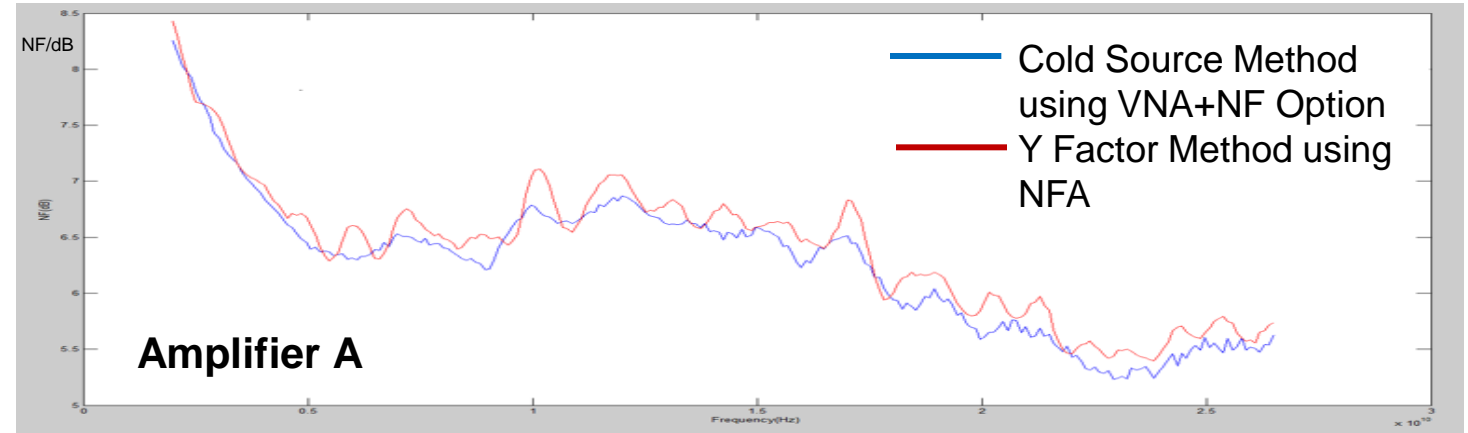
4.4 NF Measurement based on VNA

How to measure NF using a VNA - 4

Step 4: Connect DUT and Measure

➢ The E-cal and noise source is only needed in calibration process.

NF result comparison using a VNA and NFA

Amplifier A

Amplifier B

Both methods have a similar result. Cold source method based on VNA can give a more accurate and smooth value.

4.5 NF Measurement based on VNA

**Highest measurement efficiency and accuracy to characterize the component comprehensively**

- Single connection for S parameters, Noise figure, Noise parameters, Compression and Inter-modulation distortion etc.

- Faster speed: at least 4-Times faster than normal NFA

- Multiple displaying types to express the results.

Screenshot of Noise Parameters Measurement using VNA

Low Noise Amplifier IC test
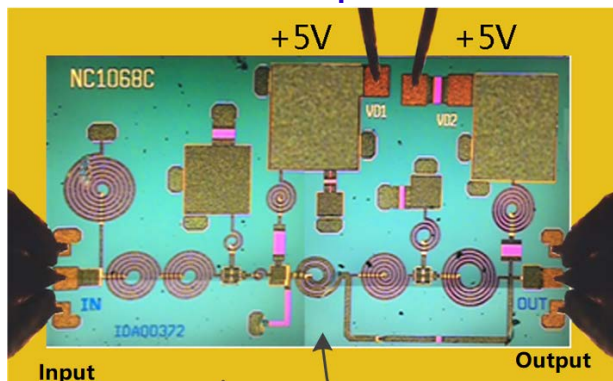
4.6 NF Measurement based on VNA

Perfect solution for on-wafer Noise Figure and S parameters test simultaneously.

- ➤ No need Noise Source or E-cal during measurement process;
- ➤ Perfectly work using coaxial, waveguide interfaces;
- ➤ Accurate and repeatable on-wafer device test for noise parameters and S parameters
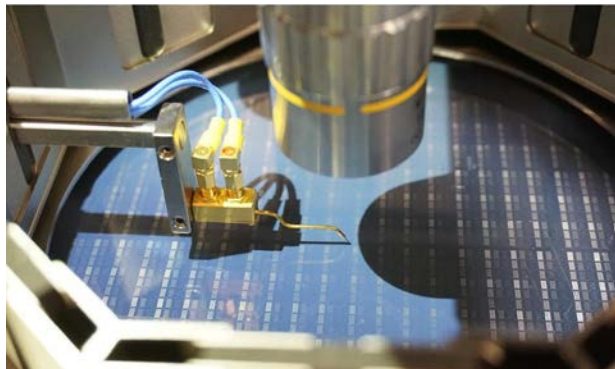
Probe Station
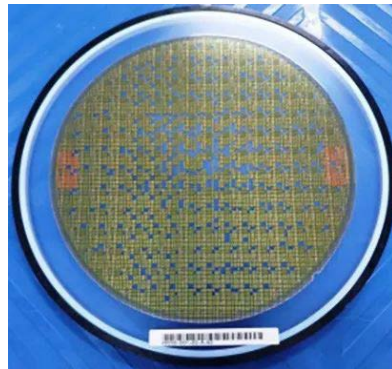
Wafer Under Test

On-wafer one stop full parameters measurement platform

Http://www.ceyear.com

5 NF Measurement Method Comparison
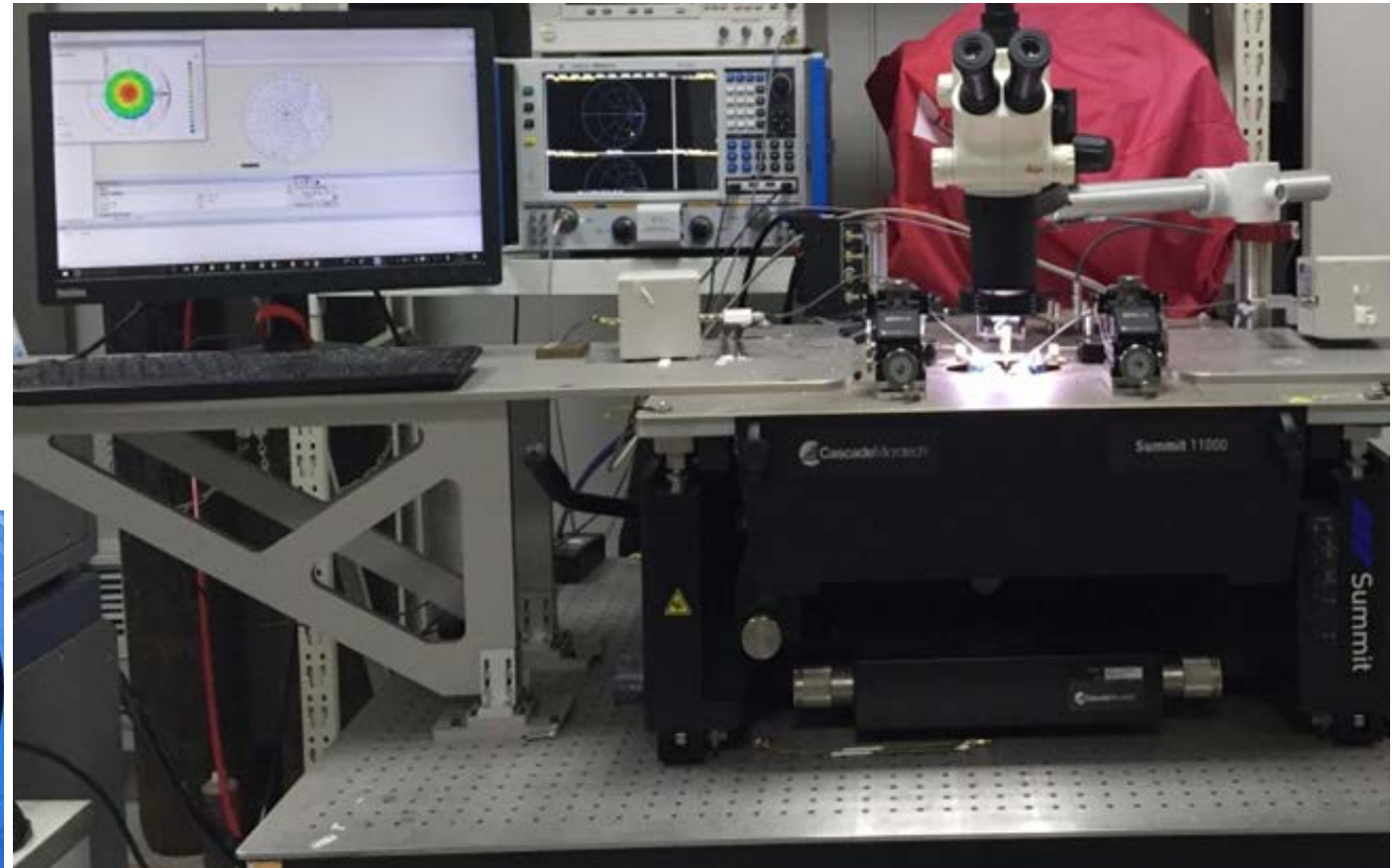
Concerns of NF Measurement Methods Selection

	Method	Configuration	Features	Measurable Parameters	Accuracy	Cost
A	Y Factor	3986 NF Analyzer 16603/4 Noise Source	Dedicated Instrument	NF, Gain	high	low
		4051 Spectrum Analyzer, Preamp and NF option 16603/4 Noise Source	Options on Spectrum Analyzer	NF, Gain	low	medium
B	Cold Source	3672 VNA, NF option 16603 Noise Source	Option on VNA, on-wafer test	NF, Gain, S-parameters	higher	high
		3672 VNA, NF option 16603 Noise Source 2040X Electronic Calibration Kits	Option on VNA, 0n-wafer test, wider NF test range	NF, Gain, S-parameters	Highest	higher

1 Ceyear Advantage –Cost-efficient Solution

Self-contained R&D Ability

Full R&D Ability of signal generation, signal reception and analysis in RF, microwave, mmW and THz.

China Domestic Resource

As the largest T&M instrument provider in China, Ceyear has an efficient test ecosystem.

Local Partner and Office

Ceyear has local partner and office in many area and have professional team to provide timely service.

Flexible Business Types

Special pricing and banking policy allow flexible business. Powerful customization and co-R&D facility

Http://www.ceyear.com

2 Typical Industry Analysis

IC and component Test
Chips or module of LNA, Mixer, up/down converter

Colleges & Universities
Electronic Engineering
Material science and engineering
Radio Physics

Space Exploring and Aviation System
Signal receiving modules or chains or modules; Receiver front-end

Metrology and Accreditation
National, Industrial stands
Factory standards

Radar and Satellite Comm
Signal receiving modules or chains or modules; Receiver front-end.

3 Typical Cases – University, Institute and Company

	Customer	Methods	Configuration
1	Qingdao RPM Electronics Co., Ltd	3986B Noise Figure Analyzer	Security Radar R&D
2	JEZETEK Group	3986D Noise Figure Analyzer	ICs NF and gain test, Receiving circuits test
3	Xidian University	3986D Noise Figure Analyzer	Ics and modules NF test, circuits test, Teaching and R&D
4	Beihang University （BUAA）	3986E Noise Figure Analyzer	ICs NF and gain test, circuits test, Teaching and R&D
5	Nanjing University of Science & Technology	3986H Noise Figure Analyzer	NF and gain test, circuits test, Teaching and R&D
6	The 55th，38th institute of CETC	3672E Vector Network Analyzer with NF option, 824IIL 88.5GHz extender	ICs measurement, Communication system R&D
7	China National Institute of Metrology	3672E Vector Network Analyzer with NF option	Metrology system R&D and standards constitution
8	China Aerospace Science and Industry Corporation	4051E Spectrum/Signal Analyzer with NF option	Communication system R&D, IC/Module R&D,
9	Institute of Electronics, Chinese Academy of Science	4051H Spectrum/Signal Analyzer with NF option	ICs R&D, communication receiver test
10	Beijing Remote Sensing Technology Institute	3986C Noise Figure Analyzer	Receiver circuits test, system confirmation
11	Shanghai Institute of Microsystem and information Technology	3986E Noise Figure Analyzer with 110GHz extender	Component design and microsystem confirmation
12	China Academy of Space Technology（CAST）	3986F Noise Figure Analyzer with	Space communication receiver R&D
13	IC Valley Microelectronics Co., Ltd	3986A Noise Figure Analyzer	ICs manufacture line
14	HW Technologies CO., Ltd	3986D Noise Figure Analyzer and 4051E Spectrum Analyzer	Communication system R&D, 4G/5G R&D and Manufacture
15	Addvalue Innovation Pte Ltd	3986A Noise Figure Analyzer	Satellite communication device R&D

THANKS !

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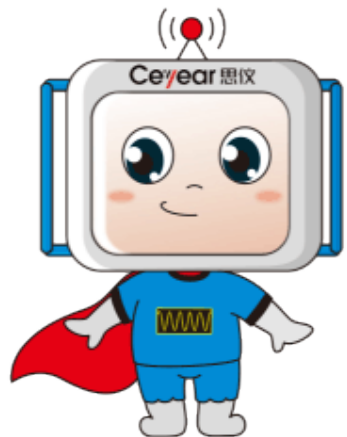
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