



COPPER MOUNTAIN
TECHNOLOGIES

FET1854

FREQUENCY EXTENSION MODULE

Operating Manual

July 2018

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Introduction

This Operating Manual contains design and specification, information, a functional overview, and detailed operation procedures for the FET1854 Frequency Extension Module (hereinafter – Module) to ensure effective and safe use of its technical capabilities by a user.

The Operating Manual contains the following data:

- General information on the Frequency Extension Module;
- The list of vector network analyzers (hereinafter – Analyzers) which can be used in combination with Modules;
- Operation safety requirements;
- Connection procedure;
- Measurement procedure.

The Modules are operated in combination with the Cobalt Series Vector Network Analyzers, creating a transmission and reflection coefficient measurement system. The Module cannot be operated in stand-alone mode. The Module must connect to an Analyzer to enable measurement mode.

For more detailed information about the frequency extension system that combines the Module and Cobalt Series Vector Network Analyzers visit:

<http://coppermountaintech.com/frequency-extension/>

The user should read and understand the following documentation before operating the Module:

- This Operating Manual;
- The Operating Manual of the Analyzer operated in combination with the Module;
- The Analyzer Programming Manual (if remote control function is desired).

Maintenance and operation of the Module should be performed by qualified engineers with basic experience operating microwave circuits.

The manufacturer reserves the right to introduce any modifications which do not affect rated metrological characteristics to Module design or this documentation without notice.

The manufacturer is not responsible for any consequences resulting from misuse of the Module, including violation of safety rules or other necessary precautions.

1 Safety Instructions

Carefully read the following safety instructions before operating the Module. Observe all precautions and warnings provided in this Operating Manual for all operation, service, and repair of the Module.

The Modules must be grounded using the control cable connected to the Analyzer.

Additional safety instructions are stated in the Operating Manual of the Analyzer in combination with which the Modules are used.

CAUTION:

NEVER CONNECT OR DISCONNECT THE MODULE CONTROL CABLE WHEN THE ANALYZER IS POWERED.

OPERATORS MUST NOT REMOVE SAFETY LABELS OR ATTEMPT TO REPAIR OR SERVICE THE MODULE.



Only thoroughly trained personnel with the required skills and knowledge of safety precautions should use the Module.

Before operating the Module, it is recommended to connect it to the device under test.

Exceeding the maximum input power of the RF signal or the maximum DC peak voltage as indicated on the Module housing can damage the Module.



The Modules are powered from the internal power supply of a Cobalt Series Analyzer. Other power sources can damage the Module.

Visually inspect the control cable for damage before connecting the Module.

Electrostatic Discharge Protection

Static charge can build up on a user's body and damage sensitive internal components. To avoid damage from electrostatic discharge, observe the following:



- Always use a desktop anti-static mat under the DUT.
- Always wear a grounding wrist strap connected to the desktop anti-static mat via daisy-chained 1 M Ω resistor.
- Connect the post marked on the body of the Extender to the body of the DUT before you start operation.

Observe all general safety precautions related to operation of electrically energized equipment.

2 General Overview

2.1 Description

The Modules are operated in combination with Cobalt Series Vector Network Analyzers creating the transmission and reflection coefficients measurement system in the extended frequency range.

The Cobalt Series includes Analyzers with a configurable front panel enabling direct Module connection. The back panel of the Analyzers also features connectors for control of signal transmission and electric power supply. The list of Analyzers supported is shown in the following table.

Table 2.1 Supported Analyzers

Analyzer	Analyzer operating frequency range
Two-port analyzers	
C4209	100 kHz to 9 GHz
C4220	100 kHz to 20 GHz
Four-port analyzers	
C4409	100 kHz to 9 GHz
C4420	100 kHz to 20 GHz

The number of simultaneously operated Modules depends on the Analyzer hardware configuration used.

Remote control is carried out using the COM/DCOM or TCP/IP Socket protocols.



Figure 2.1 Module Appearance


2.2 Specifications

The specifications for the Modules can be found in the corresponding data sheet, which is located on the website.

2.3 Measurement Capabilities

The Analyzer software controlling the Module's operation as a component of the measurement system features a wide set of functions. A brief description is given below. The detailed description of these functions is provided in the Analyzer Operating Manual.

Measurement capabilities are divided into the following groups:



<u>General data</u>
<u>Sweep setup features</u>
<u>Trace display functions</u>
<u>Calibration</u>
<u>Data analysis</u>
<u>Mixer / converter measurements</u>
<u>Other features</u>
<u>Remote control</u>

General data

Measured parameters

If one module is used:

S_{11} ;

If two modules are used:

$S_{11}, S_{21}, S_{12}, S_{22}$;

If four modules are used:

$S_{11}, S_{12}, S_{13}, S_{14}$

$S_{21}, S_{22}, S_{23}, S_{24}$

$S_{31}, S_{32}, S_{33}, S_{34}$

$S_{41}, S_{42}, S_{43}, S_{44}$

Number of measurement channels

Up to 16 logical channels. Each logical channel is represented on the screen as an individual channel window. A logical channel is defined by such stimulus signal settings as frequency range, number of test points, power level, etc.

Data traces

Up to 16 data traces can be displayed in each channel window. A data trace represents one of the following parameters of the DUT: S-parameters, response in the time domain, or input power response.

Memory traces

Each of the 16 data traces can be saved into memory for further comparison with the current values.

Data display formats

Logarithmic magnitude, linear magnitude, phase, expanded phase, group delay, SWR, real part, imaginary part, Smith chart format, and polar format.

Sweep setup features

Sweep type

When the stimulus power is a fixed value: Linear frequency sweep, logarithmic frequency sweep, and segment frequency sweep. When frequency is a fixed value: linear power sweep.

Sweep trigger

Trigger modes: continuous, single, hold. Trigger sources: internal, manual, external, bus.

Trace display functions

Trace display	Data trace, memory trace, or simultaneous data and memory traces.
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Trace math	Data trace modification by math operations: addition, subtraction, multiplication or division of measured complex values and memory data.
------------	---

Electrical delay	Calibration plane compensation for delay in the test setup, or for electrical delay in a DUT during measurements of deviation from linear phase.
------------------	--

Phase offset	Phase offset in degrees.
--------------	--------------------------

Calibration

Calibration	Calibration of a test setup (which includes the Analyzer, Modules, cables, and adapters) significantly increases the accuracy of measurements.
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Calibration methods	<p>The following calibration methods of various sophistication and accuracy enhancement are available:</p> <ul style="list-style-type: none">- reflection and transmission normalization;- full one-port calibration;- one-path two-port calibration;- full 2/3/4-port calibration;- 2/3/4-port TRL calibration.
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Mechanical calibration kits	A user can select a predefined calibration kit from various manufacturers or define additional calibration kits.
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Error correction interpolation	When a user changes such settings as start/stop frequencies and number of sweep points compared to the settings of calibration, interpolation or extrapolation of the calibration coefficients will be applied.
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Data Analysis

Port impedance conversion	The function converts S-parameters measured at the analyzer's nominal port impedance of 50 Ω into values which would be found if measured at a test port with arbitrary impedance.
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De-embedding	The function mathematically excludes the effects of a fixture circuit connected between the calibration plane and the DUT. This circuit should be described by an S-parameter matrix in a Touchstone file.
Embedding	The function mathematically simulates the DUT parameters after virtual integration of a fixture circuit between the calibration plane and the DUT. This circuit should be described by an S-parameter matrix in a Touchstone file.
S-parameter conversion	The function converts the measured S-parameters to the following parameters: reflection impedance and admittance, transmission impedance and admittance, and inverse S-parameters.
Time domain transformation	The function performs data transformation from frequency domain into response of the DUT to various stimulus types in time domain. Modeled stimulus types include bandpass, lowpass impulse, and lowpass step. Various window shapes help a user optimize the tradeoff between resolution and level of spurious sidelobes.
Time domain gating	The function mathematically removes unwanted responses in time domain, obtaining frequency response without the influence of fixture elements. The function applies a reverse transformation back to the frequency domain from a user-defined span in the time domain. Gating filter types include bandpass or notch. For better tradeoff between gate resolution and level of spurious sidelobes maximum, wide, normal, and minimum filter shapes are available.
Balanced measurements	Balanced measurement function converts unbalanced S-parameters into their balanced equivalents by means of combining an arbitrary port pair into logic balanced port. Four configurations of measured devices with various combinations of balanced and unbalanced ports are supported.

Mixer / converter measurements

Scalar mixer/ converter measurements	The scalar method measures scalar transmission S-parameters of mixers and other devices with different input and output frequencies. No external mixers or other devices are required. The scalar method employs port frequency offset when there is a difference between receiver frequency and source frequency.
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Vector mixer/ converter measurements	The vector method measures mixer transmission S-parameter magnitude and phase. The method requires an external mixer and an Local Oscillator (LO) common to both the external mixer and the mixer under test.
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Other features

Familiar graphical user interface	Graphical user interface based on the Windows operating system.
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Printout/saving of traces	The traces and data printout function has a preview feature. Previewing, saving and printing can be performed using MS Word, Image Viewer for Windows, or the Analyzer Print Wizard.
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Remote control

COM/DCOM, TCP/IP Socket	The Analyzer software operating on the Windows-based PC supports COM-Server and TCP/IP Socket-Server control and data-exchange protocols. These protocols have similar features. A user can select a user-friendly protocol. COM-Server runs the user program on the Analyzer PC. TCP/IP Socket-Server exchanges textual commands according to SCPI standard.
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2.4 Principle of Operation

The Modules are operated in combination with Analyzers. The system is controlled by the Analyzer software. The Module does not feature a stand-alone mode and it cannot be used for measurements if it is not connected to an Analyzer.

The Modules are ultra-compact devices. They include the following basic elements: test/RF and LO signal frequency multipliers, a wide-band power amplifier with internal ALC system, directional couplers and frequency converters. They also include power supply circuits and control boards. The Module block diagram is shown in Figure 2.6.

Measurement system includes:

- The Cobalt Series Analyzer with the configurable front panel for connection of Modules;
- Frequency Extension Modules (modules);
- Cables for Module connection to Analyzer.

The Analyzer generates RF and LO signals in the specified frequency and power ranges. The signals are transmitted to the Module through RF and LO cables included in the standard delivery set. Diagrams of Module/Analyzer connection are shown in Figures 2.7 and 2.8.

Frequency Extension Module		
RF IN – test signal input		
Input frequency range, GHz:		Output f range, GHz:
Range 1	4.5 to 8.0 (x4)	18 to 32
Range 2	4.00 to 6.25 (x8)	32 to 50
Range 3	6.25 to 6.75 (x8)	50 to 54
Input power level:	-4 to -1 dBm	
LO IN – LO signal input		
Input frequency range, GHz:		Output f range, GHz:
Range 1	4.5 to 9.0 (x4)	18 to 36
Range 2	4.00 to 6.75 (x8)	36 to 54
Input power level	-6 to -3 dBm	

The frequency of the RF signal transmitted from the Analyzer is multiplied, filtered, and scaled in the Module to level depending on user settings. To ensure the preset power level at the Module output and its stability over time, the automatic level control system of over 20 dB is applied.

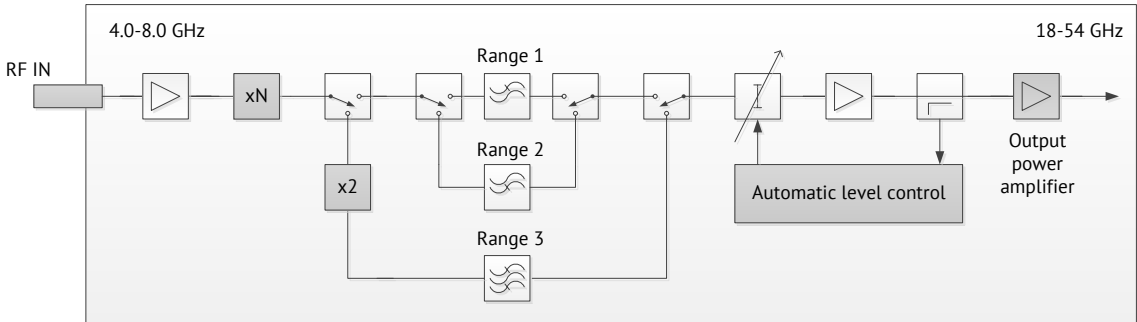


Figure 2.2 Test signal generation with output power control

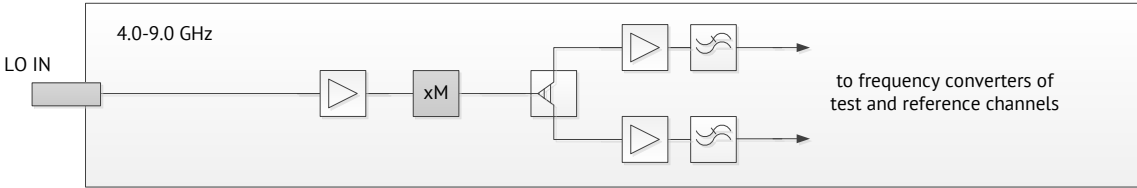


Figure 2.3 LO signal source group

Then the generated RF signal is transmitted to the test port via directional couplers. The directional couplers extract the incident wave, the wave transmitted through the DUT, and the reflected wave. These signals are supplied to frequency converters of test and reference channels. The LO signal from the Analyzer is used for conversion. The converted IF signals are amplified and passed to the Module output and then the Analyzer input via IF cables.

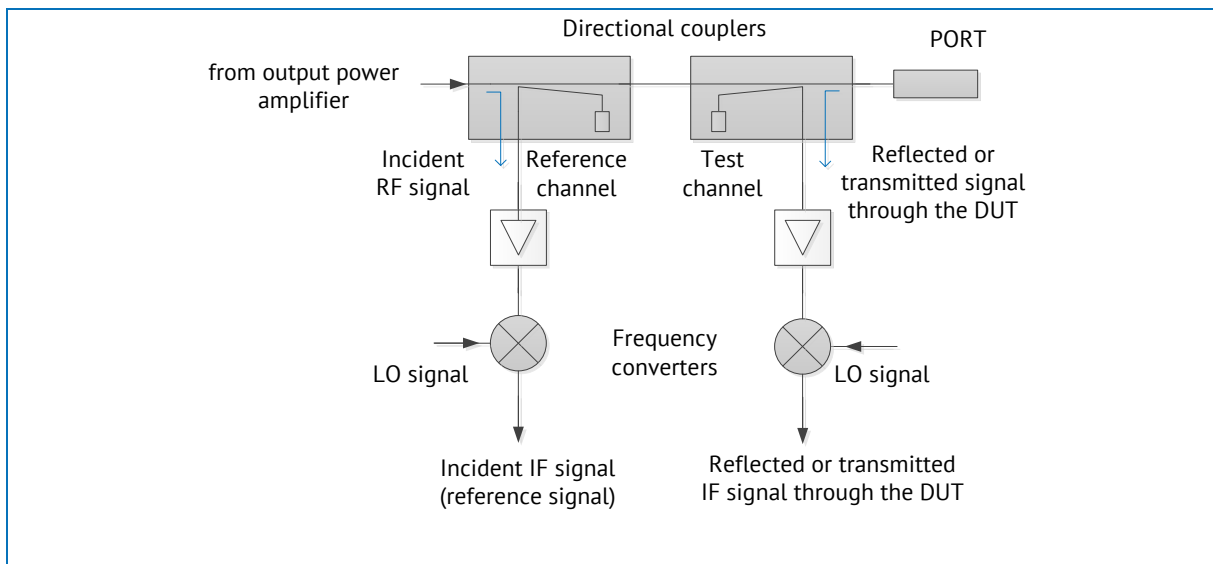


Figure 2.4 Signals separation and conversion group

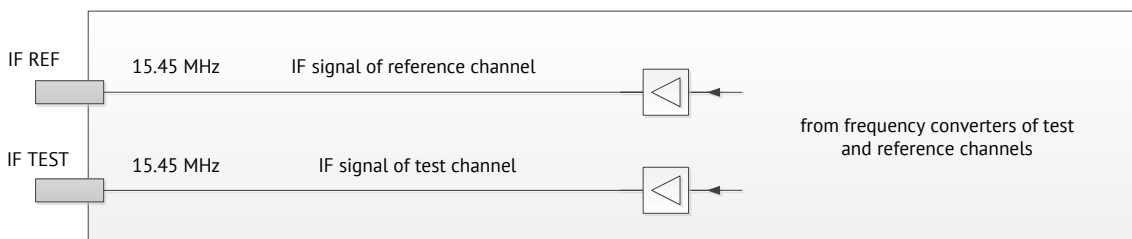


Figure 2.5 IF signals generation group

In turn, the Analyzer performs digital signal processing on the IF signals. An external PC uses the Analyzer software to calculate and display measurement results for complex transmission and reflection coefficients. Its principle of operation is based on comparison of magnitude and phase of source signal (incident wave) and magnitude and phase of signals transmitted through and reflected by the DUT.

Frequency Extension Module

IF REF and IF TEST Outputs

Output frequency, MHz	15.45
Max output power level, dBm	0

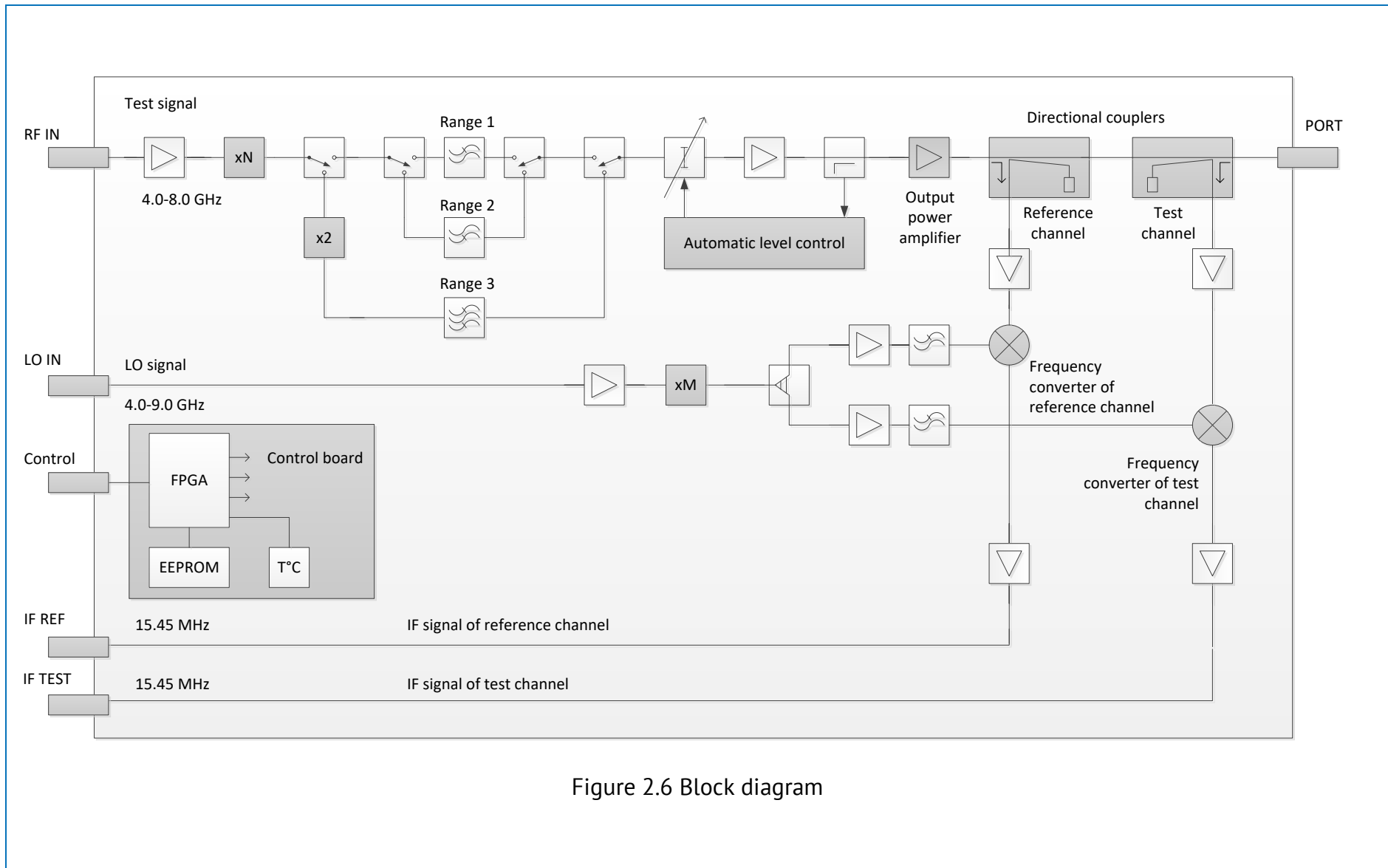


Figure 2.6 Block diagram

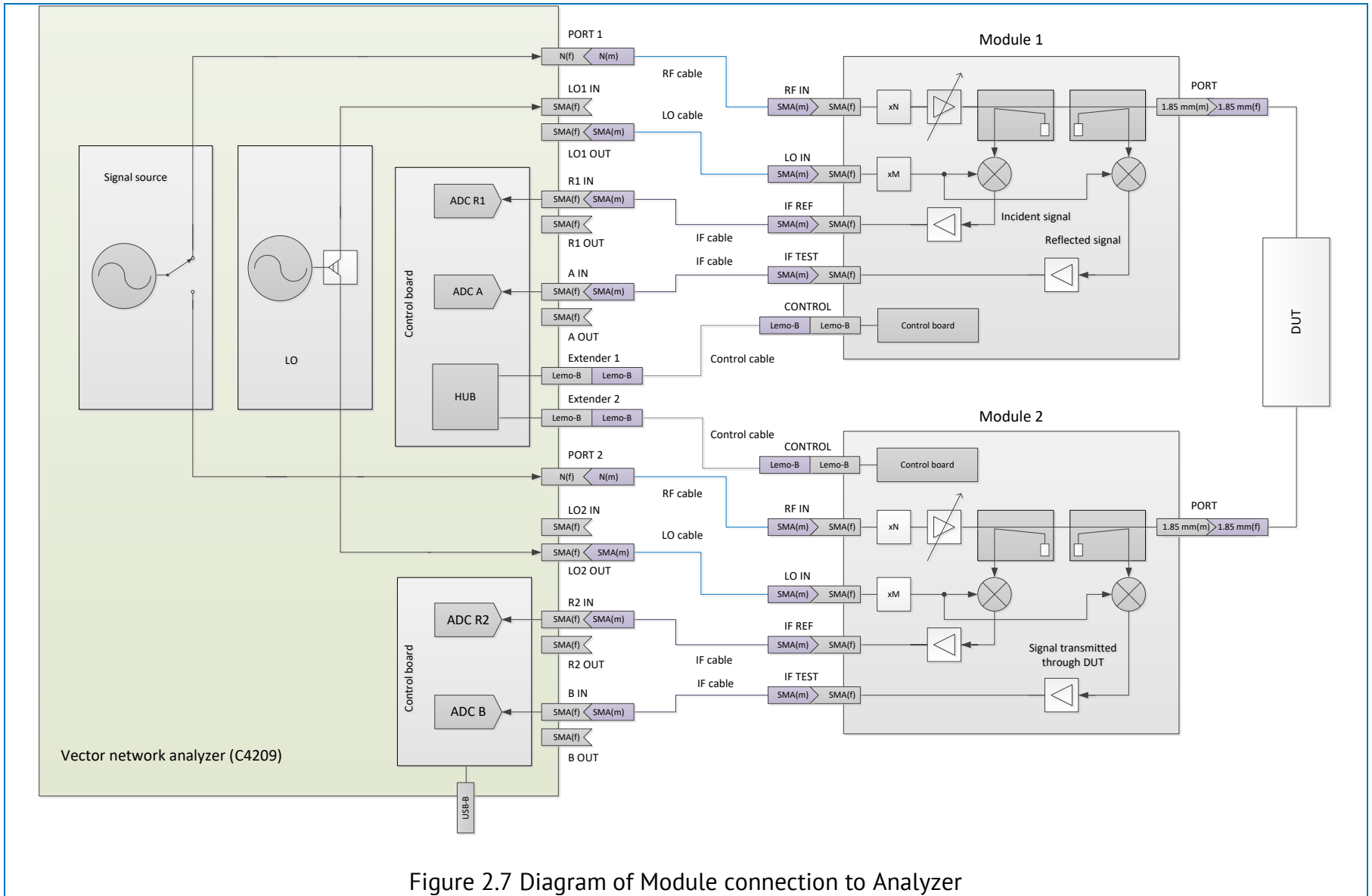


Figure 2.7 Diagram of Module connection to Analyzer

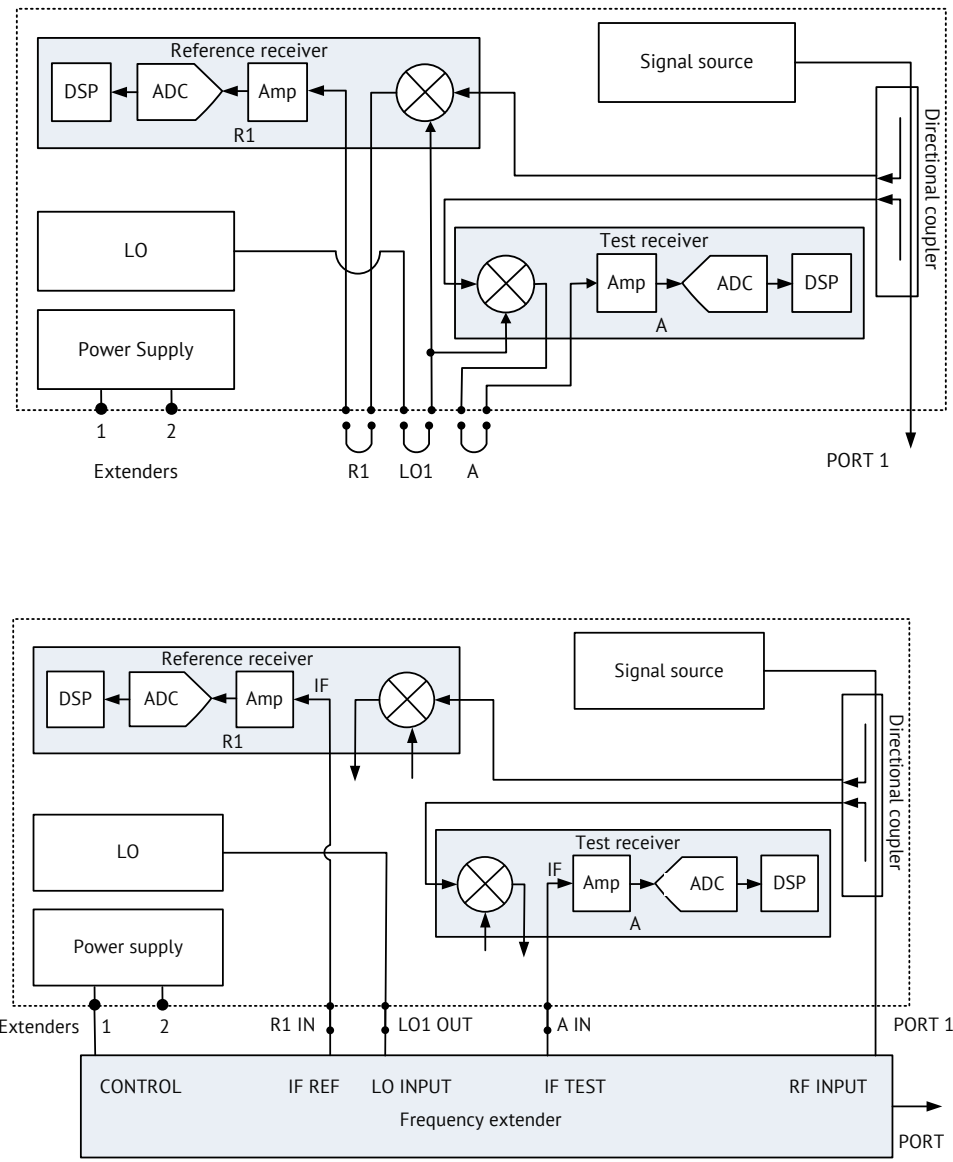


Figure 2.8 Diagram of Module connection to Analyzer

The Modules are powered and controlled directly from an Analyzer. The number of simultaneously operating Modules depends on the model of Analyzer used.

3 Preparation for Use

3.1 General Information

If a Module and accessories have been kept in an environment other than the rated operating conditions, leave them in facilities with normal operating conditions for at least two hours prior to operation.

Unpack the Module if it is in a package.

The surface area must be sufficient to hold the Module, its accessories, and any DUTs.

Install the Module on a flat surface so that all of its feet are in full contact with the surface and the connectors are easily accessible. Connected devices must be located at or directly above the work surface.

The maximum distance from Module to Analyzer depends on the RF, LO, and IF cable lengths. Check the cable lengths before operating the Module.

Vent holes in the Module housing must not be obstructed during operation. Turn the analyzer's power supply off before inspecting the housing.

To avoid damage from electrostatic discharge, certain safety precautions must be observed at the work place. Please review the Electrostatic Discharge Protection instructions on page 5 of this Operating Manual.

Before operating the Module, visually inspect it along with its accessories.

3.2 Visual Inspection

Perform a visual inspection to make sure the Module is free from any visible mechanical damage.

The visual inspection procedure is as follows:

- Check the Module for presence and integrity of the manufacturer's seals. There should be no signs of the Module housing having been opened.
- All cables must be intact.
- The Module housing should be free from deep scratches, dents, rust, and stains from liquid or corrosive vapor. The coating and marking must be intact.

- Visually inspect coaxial connectors of all devices for damages. Clean the connectors if any particles are found inside the connectors.

- Check the mating plane and conductive surfaces of connectors for mechanical damage (dents, deep scratches, worn plating, etc.).



Do not operate the device if you detect any mechanical damage on a connector. Damaged connectors should be discarded in order to prevent its further usage and damage of other good connectors.

4 Operation Procedure

4.1 Location of Controls

Frequency Extension Module



Figure 4.1 Front panel

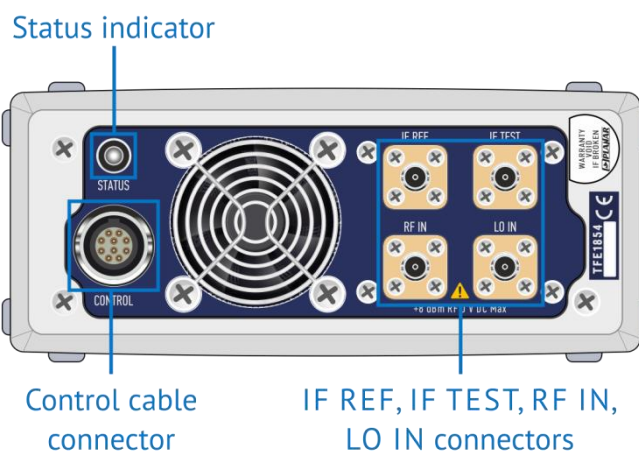


Figure 4.2 Rear panel

C4209 Vector Network Analyzer

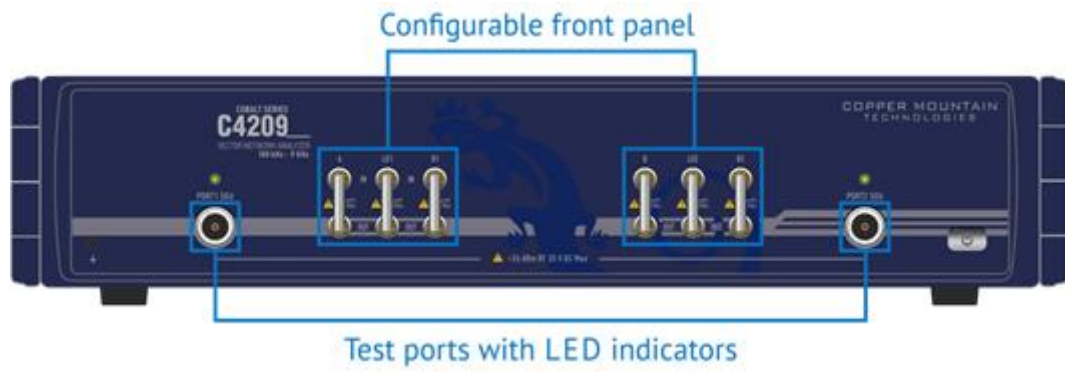


Figure 4.3 Front panel

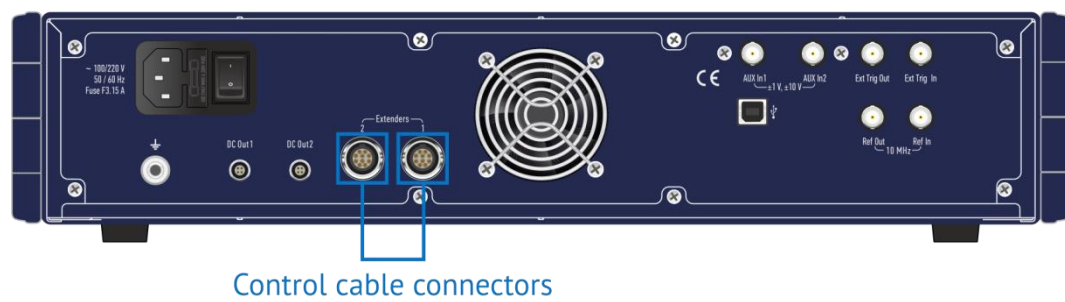


Figure 4.4 Rear panel

C4409 Vector Network Analyzer

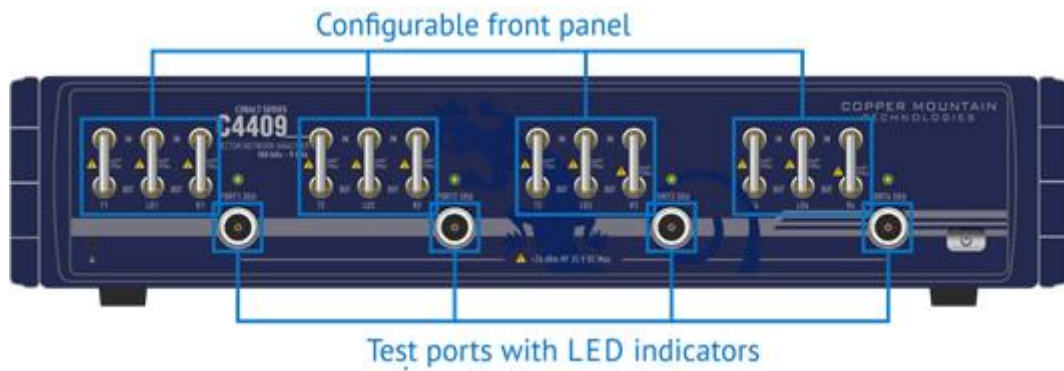


Figure 4.5 Front panel

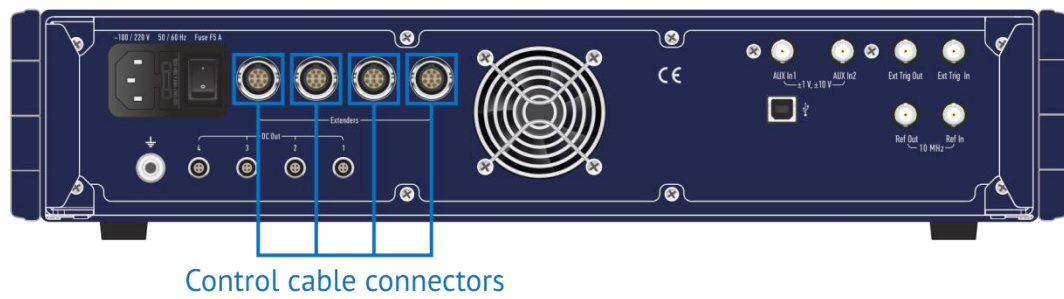


Figure 4.6 Rear panel

C4220 Vector Network Analyzer

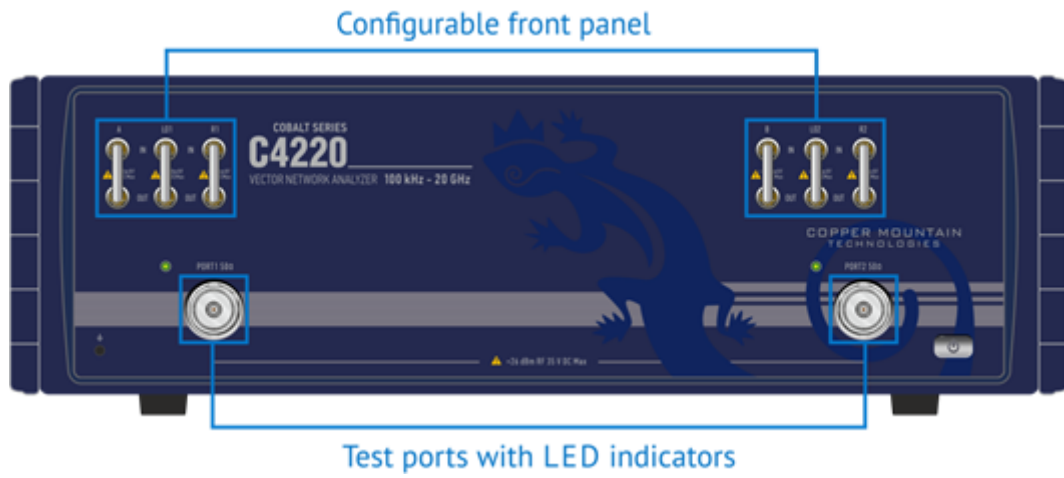


Figure 4.7 Front panel

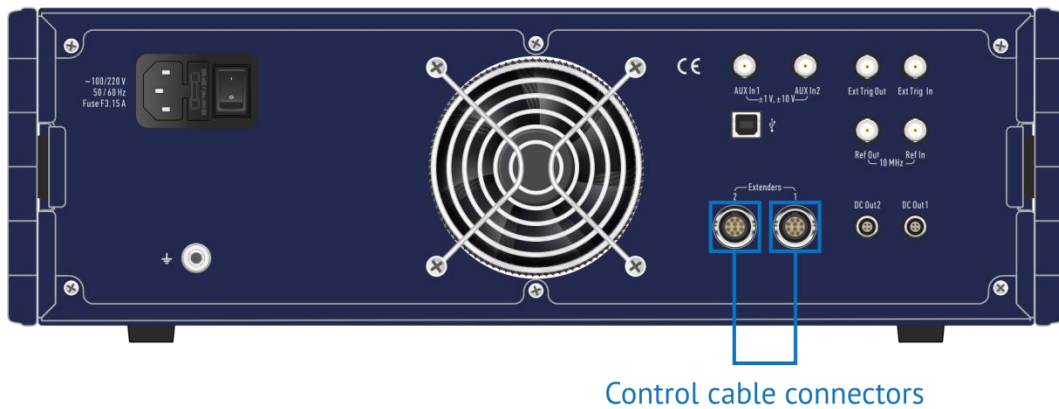


Figure 4.8 Rear panel

C4220 Vector Network Analyzer

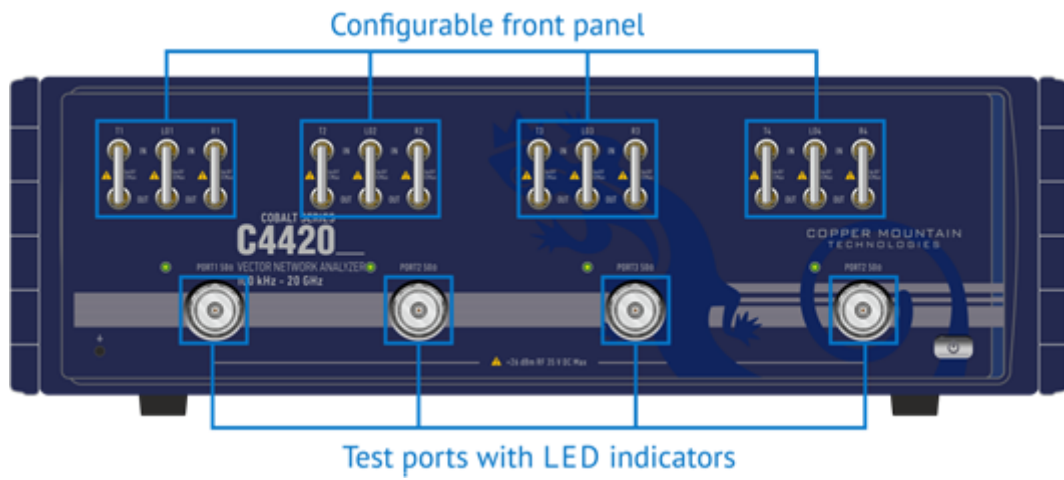


Figure 4.9 Front panel

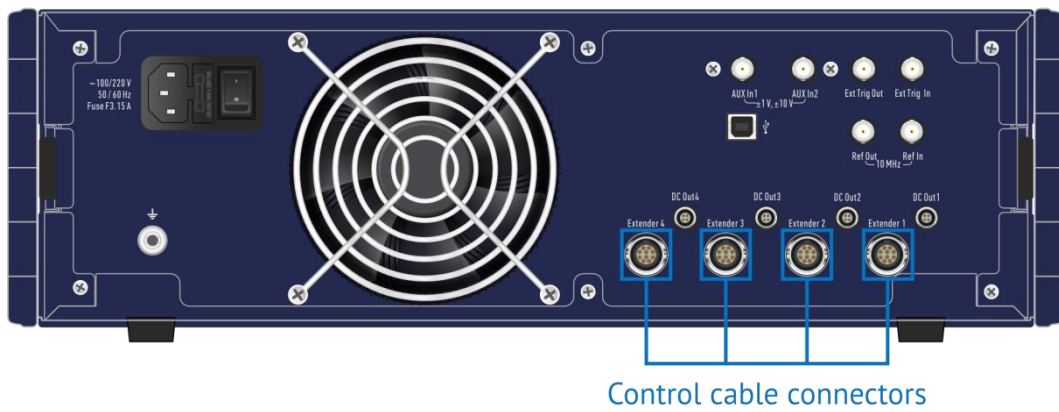


Figure 4.10 Rear panel

4.1.1 Module Front Panel

Test port



The test port serves as an RF test signal source and as a DUT signal receiver.

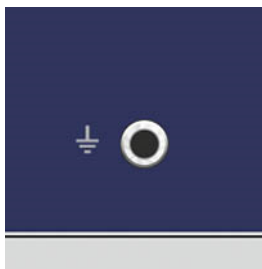
If one test port is connected, the DUT reflection parameters can be measured.

Connection of 2, 3 or 4 test ports enables measurement of additional S-parameters.

Caution!

Exceeding the max RF signal input power or the max DC voltage can damage the Module.

Ground terminal

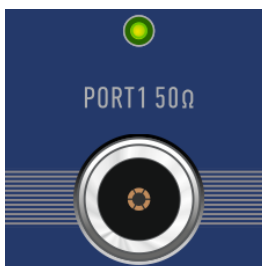


To avoid damage from electrostatic discharge, connect the ground terminal to the DUT housing.

Such connection balances potentials between the Module housing and the housing of an active externally-powered device, preventing damage of both devices' input circuits.

4.1.2 Analyzer Front Panel

Test ports with LED indicators

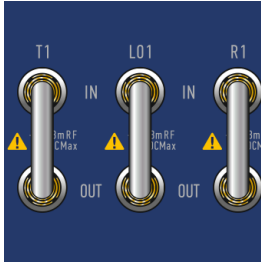


The Analyzer test ports serve as test signal sources.

The LED indicator indicates that a test port is serving as a signal source.



Configurable front panel



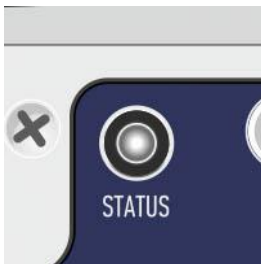
The configurable front panel is intended for the connection of external Modules.

- LO OUT – output of local oscillator signal source;
- R IN – input of reference receiver, a sequence number (R1, R2...) indicates a port number to which a receiver refers;
- A (B or T) IN – input of test receiver, a sequence number (T1, T2...) indicates a port number to which a receiver refers.

See section 2.4 for diagrams detailing connection of the Module to the Analyzer and descriptions of all applied signals.

4.1.1 Module Rear Panel

Status indicator



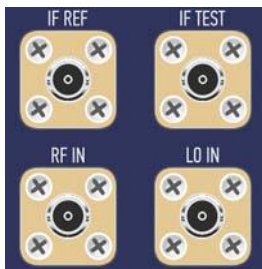
The status indicator indicates that electrical power is supplied to the Module input.

Control cable connector



The control cable connector connects the Module power supply and enables control from the Analyzer.

RF IN, LO IN, IF REF, IF TEST connectors



- RF IN – test signal source input;
- LO IN – LO signal source input;
- IF REF – output of reference channel IF signal;
- IF TEST – output of test channel IF signal.

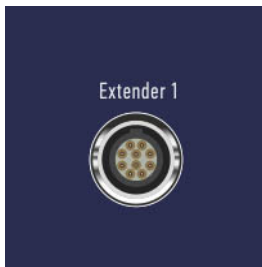
See section 4.2 for diagrams detailing connection of the Module to the Analyzer and descriptions of all applied signals.

Caution!

Exceeding the max RF signal input power or the max DC voltage indicated on the rear panel can damage the Module.

4.1.1 Analyzer Rear Panel

Control cable connector

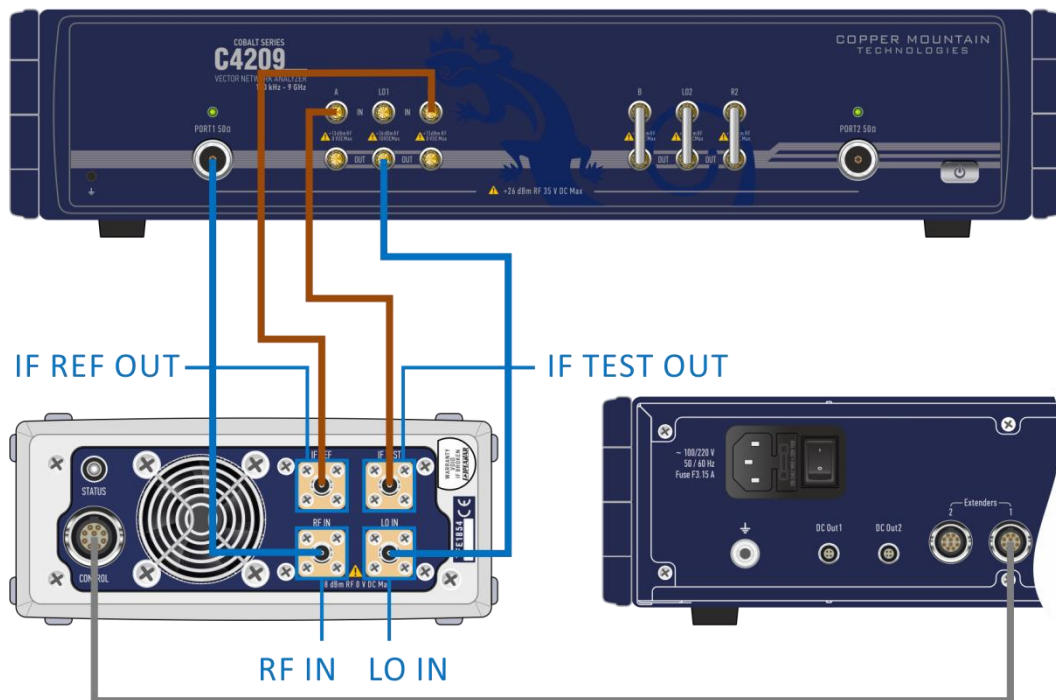


The control cable connector connects the Module power supply and enables control from the Analyzer.

The Modules are powered from a DC voltage source within the Analyzer.

4.2 Connection Diagrams

Connection diagram for C4209 Vector Network Analyzer



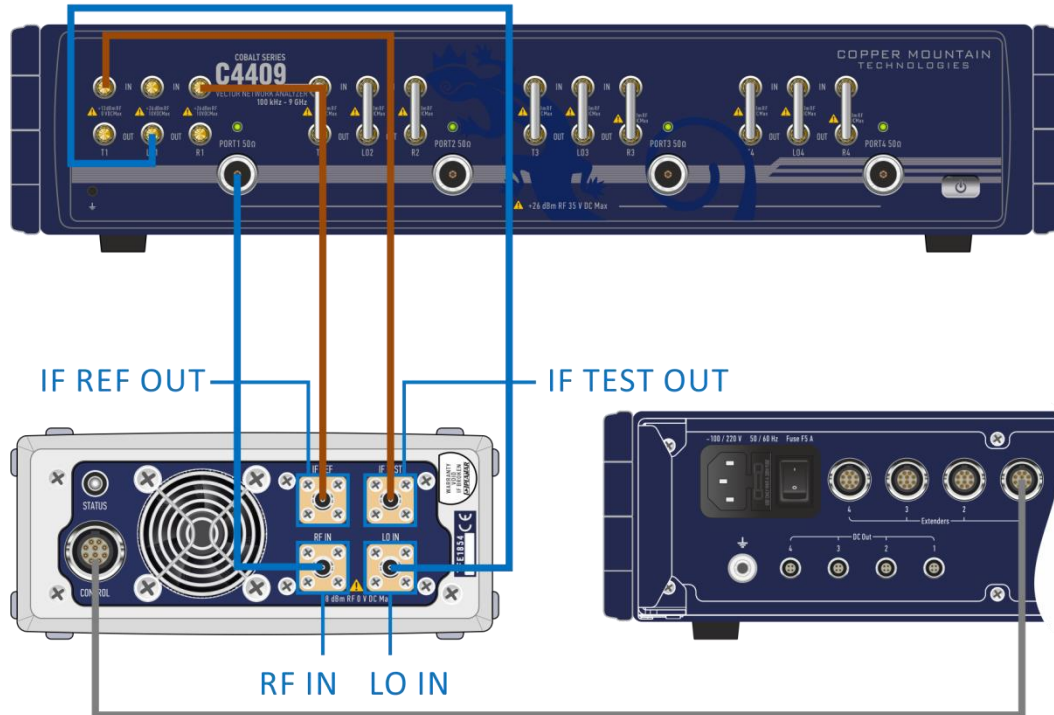
Measurement system components

Connection

Measurement system components	Module	Analyzer
C4209 Vector Network Analyzer		Analyzer
S2VNA Software		PORT 1 PORT 2
1 or 2 Frequency Extension Modules	RF IN	LO 1 OUT LO 2 OUT
1 or 2 RF cables (N, male – SMA, male)		
1 or 2 LO cables (SMA, male – SMA, male)	LO IN	
2 or 4 IF cables (SMA, male – SMA, male)	IF REF	R1 IN R2 IN
1 or 2 control cables		
Power supply and USB cables for Analyzer		
PC	IF TEST	A IN B IN
Set of calibration standards, test cables, and adapters		

Figure 4.11

Connection diagram for C4409 Vector Network Analyzer



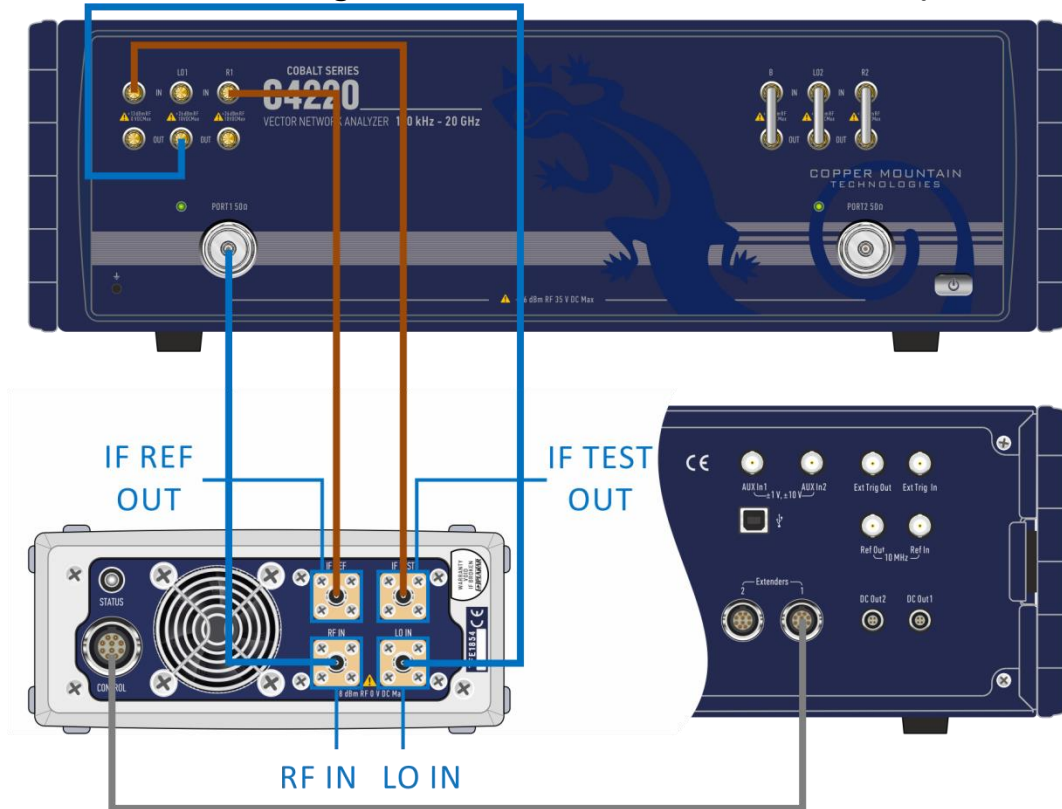
Measurement system components

Connection

C4409 Vector Network Analyzer	Module	Analyzer
S4VNA Software		PORT 1
1, 2, 3, or 4 Frequency Extension Modules		PORT 2
1 to 4 RF cables (N, male – SMA, male)	RF IN	PORT 3
1 to 4 LO cables (SMA, male – SMA, male)		PORT 4
2 to 8 IF cables (SMA, male – SMA, male)		LO 1 OUT
1 to 4 control cables	LO IN	LO 2 OUT
Power supply and USB cables for Analyzer		LO 3 OUT
PC		LO 4 OUT
Set of calibration standards, test cables, and adapters	IF REF	R1 IN
		R2 IN
		R3 IN
		R4 IN
	IF TEST	T1 IN
		T2 IN
		T3 IN
		T4 IN

Figure 4.12

Connection diagram for C4220 Vector Network Analyzer



Measurement system components

Connection

C4220 Vector Network Analyzer

S2VNA Software

1 or 2 Frequency Extension Modules

1 or 2 RF cables (SMA, male – SMA, male)

1 or 2 LO cables (SMA, male – SMA, male)

2 or 4 IF cables (SMA, male – SMA, male)

1 or 2 control cables

Power supply and USB cables for Analyzer

PC

Set of calibration standards, test cables, and adapters

Module

Analyzer

RF IN

PORT 1
PORT 2

LO IN

LO 1 OUT
LO 2 OUT

IF REF

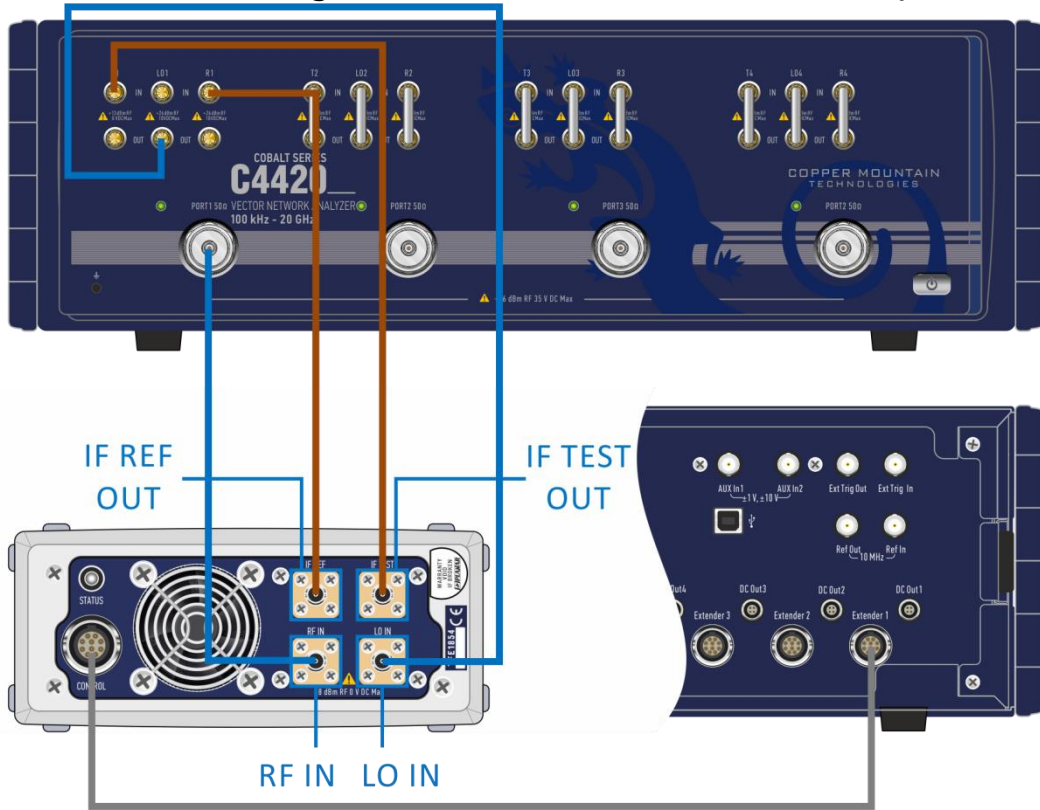
R1 IN
R2 IN

IF TEST

A IN
B IN

Figure 4.13

Connection diagram for C4420 Vector Network Analyzer



Measurement system components

Connection

	Module	Analyzer
C4420 Vector Network Analyzer		PORT 1
S4VNA Software		PORT 2
1, 2, 3, or 4 Frequency Extension Modules	RF IN	PORT 3
1 to 4 RF cables (SMA, male – SMA, male)		PORT 4
1 to 4 LO cables (SMA, male – SMA, male)		LO 1 OUT
2 to 8 IF cables (SMA, male – SMA, male)	LO IN	LO 2 OUT
1 to 4 control cables		LO 3 OUT
Power supply and USB cables for Analyzer		LO 4 OUT
PC	IF REF	R1 IN
Set of calibration standards, test cables, and adapters		R2 IN
		R3 IN
		R4 IN
	IF TEST	T1 IN
		T2 IN
		T3 IN
		T4 IN

Figure 4.14

4.3 Measurement Procedure


4.3.1. Measurement System Setup

The Module measurement system setup for simultaneous operation with the Analyzer is the following:



The Analyzer is powered from the AC mains.

Visually inspect the control cable for any damage before connecting the Module to the Analyzer.

- Switch the PC on;
 - Install the Analyzer software if it was not installed before;
 - Connect the  ground terminal at the Analyzer rear panel with the protective ground bus bar;
 - Connect the Module(s) to the Analyzer as shown in section 4.2.
-

Note

Avoid excessive bending and twisting of cables during connection.

Minimum bending radius is 45 mm. The twisting of cables during connection can damage their connectors and/or affect measurement stability.

- Connect the Analyzer with the PC using the USB cable;
 - Connect the Analyzer to AC mains using the power supply cord;
 - Switch the Analyzer on;
 - Check the Module status indicator located at the rear panel;
 - Start the Analyzer software;
-

Note

The Analyzer can be powered on or off at any time. When the Analyzer is powered on while connected to the PC, the Analyzer software will detect the Analyzer firmware. The Analyzer should be ready for operation in approximately 10 seconds.

- Select the Module and Analyzer simultaneous work mode: through the following softkeys:

Main menu > System > Misc Setup > Frequency extender > [Module name]

See section 4.3.3 for more information.

- Enter the insertion loss values for RF and LO cables;
- Set the test and LO signal output power levels at the Analyzer so that signals at the Module's RF IN and LO IN inputs match the data specified in section 2.4 adjusted for RF and LO cable insertion loss values;
- Wait for the operation mode setting at the Module(s) and the Analyzer.

The Module/measurement system shutdown sequence follows:

- Close the Analyzer software;
- Power down the Analyzer by pressing the power switch button and disabling the power supply;
- If necessary, disconnect the Module(s) from the Analyzer;
- If necessary, disconnect the DUT and the test setup;
- If necessary, disconnect the Analyzer from the AC mains from the PC, and from the protective ground bus bar.

4.3.2 Measurement Procedure

After setting up the Module and Analyzer from simultaneous operation mode, measurements can be made. The measurement procedure is as follows:

- Connect test cables and adapters compatible with the DUT ports to the Module



Use a torque wrench with an appropriate torque rating to tighten the connectors.

• Set the following parameters: frequency range, number of sweep points, IF bandwidth depending on the required dynamic range or measurement speed, and output power level. It is recommended to use IF bandwidth below 300 Hz in applications which require high dynamic measurement range and over 300 Hz in applications which require high speed;

- Select parameters to be measured;
- Select the data presentation format;

Note

Measurement parameters and data presentation format can be changed any time.

- Perform calibration depending on the available calibration kit or the required measurement accuracy (see section 4.3.4);

- When calibration is completed, connect the DUT, read the measured data, and save the results if necessary;

- To switch the Analyzer to its operating frequency range, press the following softkeys:

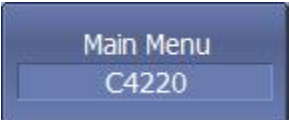
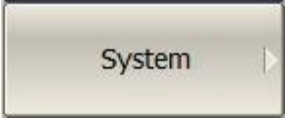

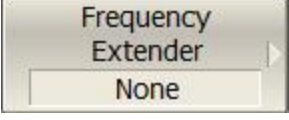
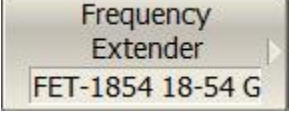
Main menu > System > Misc Setup > Frequency extender (No).

- Connect all loops on the Analyzer front panel to operate the Analyzer in its operating frequency range.

The Analyzer software that controls the Module(s) features many functions, which make the measurement process easier by using an advanced multiple marker system for searching needed values using specified criteria, mathematical and statistical analysis, filtering, saving and recalling measurement results, and setting controls. The following operating modes are supported: sweep trigger control, impedance conversion, embedding or de-embedding and time domain gating.

See the Analyzer Operating Manual for detailed measurement procedures, including a complete description of error models, description of test setups and calibration procedures, and viewing measurement results in different formats.

4.3.3 Selection of Modules in Software

	<p>Start the software. Open the main menu.</p>
	<p>Open the System menu. Main menu > System</p>
	<p>Open the Misc Setup menu. Main menu > System > Misc Setup</p>
	<p>Press Frequency Extender softkey. Main menu > System > Misc Setup > Frequency extender</p>
	<p>Select the required Module(s) in the Frequency Extender menu (FET1854).</p>



Set the test and LO signal output power levels, and RF and/or LO cables insertion losses:

- RF Port Power – test signal output power level: minus 1.4 dBm;
- LO Port Power – LO signal output power level: minus 3.3 dBm;
- RF Power Slope – RF cable insertion loss: 0.2 dB/GHz;
- LO Power Slope – LO cable insertion loss: 0.2 dB/GHz.

Note

In case the Module is connected using RF and LO cables other than those indicated in the measurement system, make sure that the test and LO signal output power level at the Module input complies with the level value indicated in section 2.4.



Setting default parameters.

Note

Use the status indicator on the rear panel to check the Module connection status.

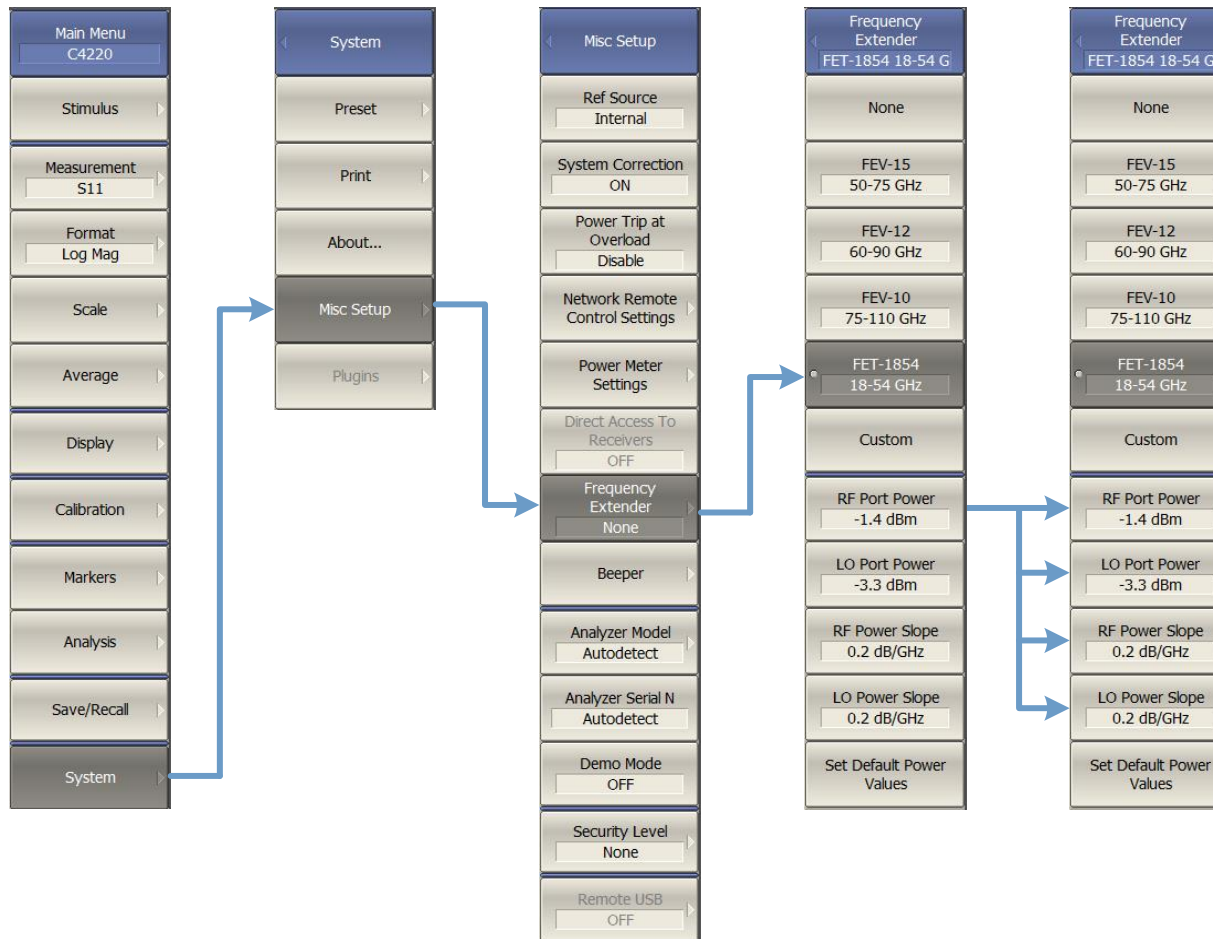


Figure 4.15 Software navigation for selecting required frequency extension modules

4.3.4 Calibration

Calibration: The process of measuring precision devices with predefined parameters with the purpose of determining systematic errors according to the Analyzer error model.

Correction: The process of mathematical compensation, via numerical reduction, for systematic errors determined during calibration with the purpose of improving measurement accuracy.

Test port: The port to which devices are connected for calibration and measurement. One test port connects a signal source and two receivers that measure signal amplitudes transmitted from and received by the port. After calibration, a test port is a connector or a waveguide through which the reference calibration plane passes.

Reference calibration plane: Calibration plane is an imaginary plane located at the ends of the connectors, which accept calibration standards during calibration.

Calibration requires usage of calibration kits including resistive matched or sliding loads, as well as calibration kits including lines.

Table 4.1 Calibration steps

Calibration step	Description
Calibration kit selection (see figure 4.16)	A calibration kit is selected so that a DUT can be connected to test ports after calibration.
Calibration method selection	Calibration methods are usually selected depending on the required measurement accuracy. The calibration method used determines which error terms will be compensated based on the model.
Calibration standards measurement in the preset frequency range – calibration procedure (see figure 4.17)	Number of measurements depends on the calibration method.
Calculation of calibration coefficients	Measured and known parameters of calibration standards are compared. Their difference is used for calculation of calibration coefficients.
	The table of calibration coefficients is saved in the Analyzer memory and used for measurements correction.

The Analyzer software supports several calibration methods. These methods differ in number and type of calibration standards used, corrected errors, and in accuracy.

Table 4.2 Calibration methods

Calibration method	Measured parameters	Standards	Accuracy
Reflection normalization	S_{11} or S_{22}	OPEN or SHORT LOAD (optional)	Low
Transmission normalization	S_{21} or S_{12}	THRU	Low
Full one-port calibration (see figure 4.18)	S_{11} or S_{22}	OPEN SHORT LOAD	High
One-path two-port calibration	S_{11}, S_{21} or S_{12}, S_{22}	OPEN SHORT LOAD THRU	Medium
Full two/three/four-port SOLT calibration (see figure 4.21)	4 / 9 / 16 S-parameters	OPEN SHORT LOAD THRU	High
Two/three/four-port TRL calibration	4 / 9 / 16 S-parameters	THRU or LINE REFLECT LINE or 2 LOADS	Very high

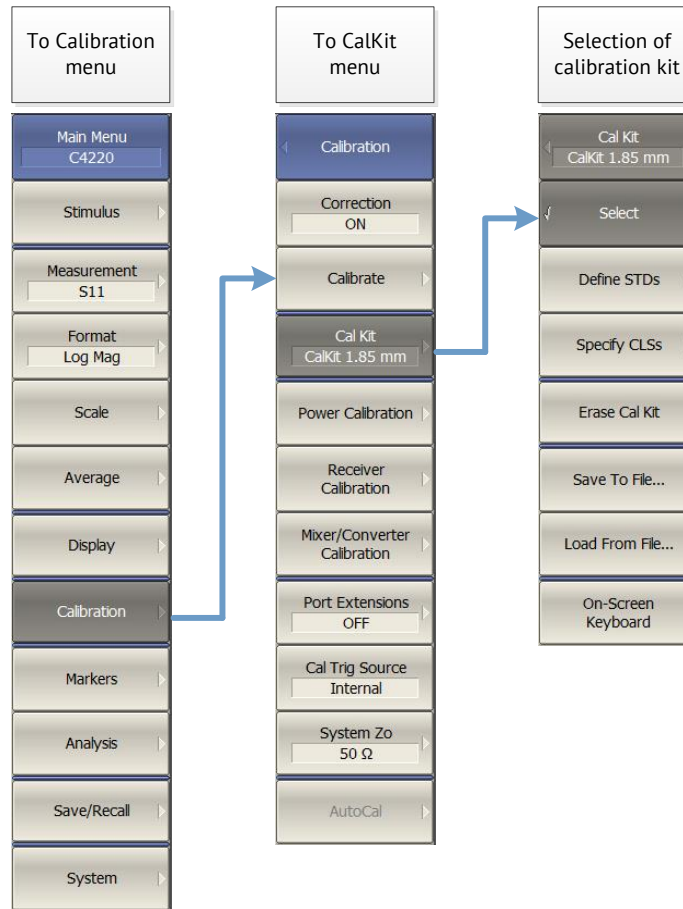


Figure 4.16 Software navigation for selecting a calibration kit from the library of preset calibration kits or entering data on a new calibration kit. The calibration kit definition can be saved to or uploaded from a file.

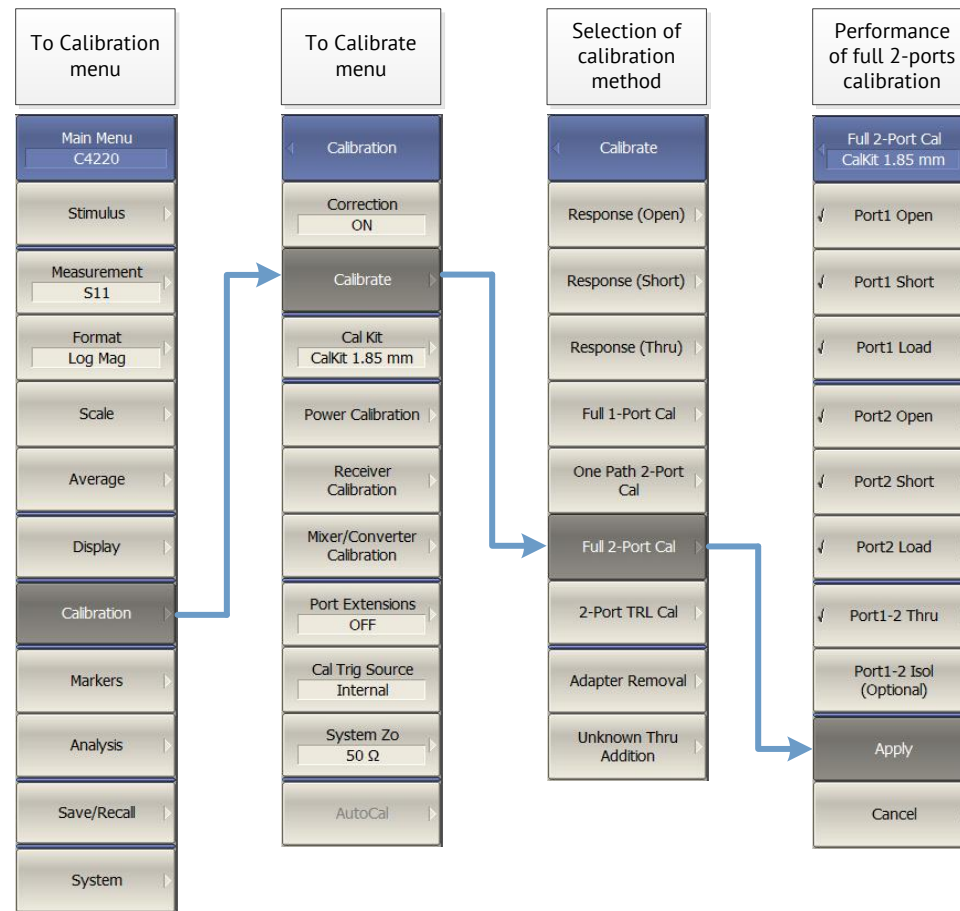
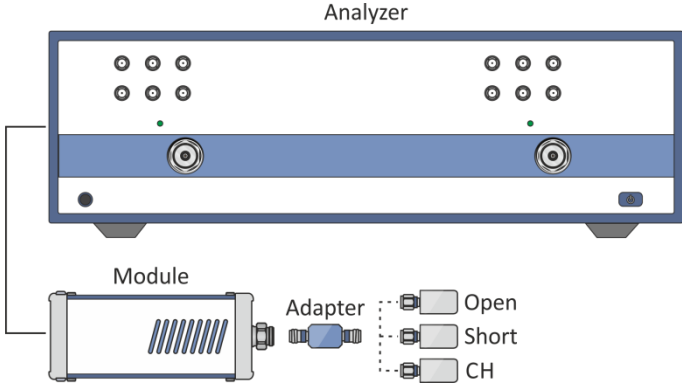
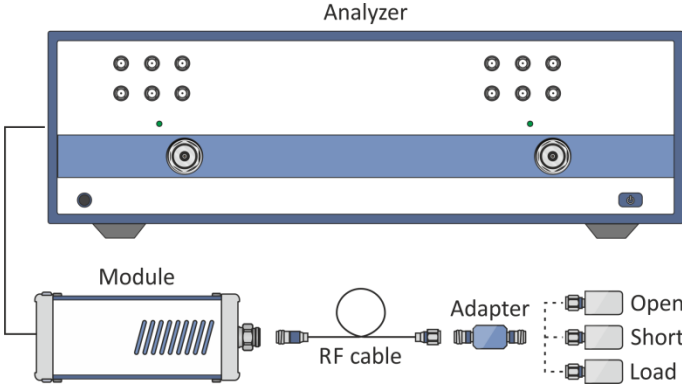


Figure 4.17 Software navigation for full two-port calibration (example)

Test cables and adapters enable connection to DUT ports. Moreover, usage of metrology-grade and instrument-grade adapters increase cables' and Module ports' service life and improves repeatability of measurement results with multiple connections.

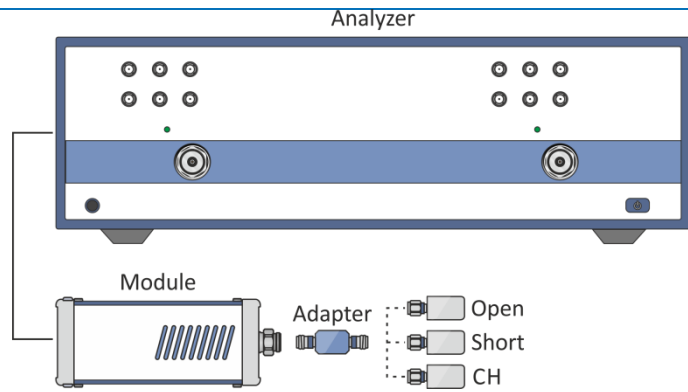


Calibration example at output of test adapter

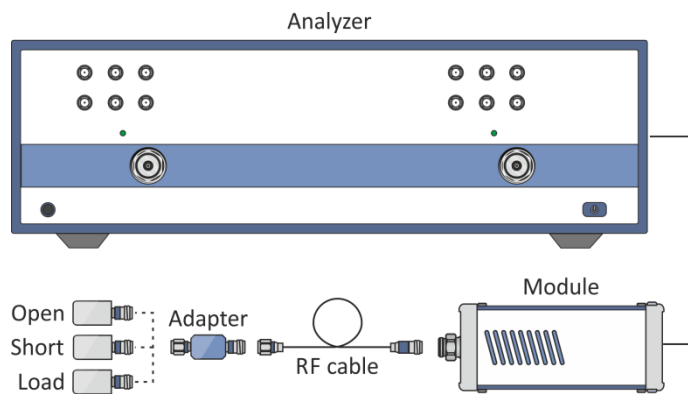


Calibration example at output of test adapter connected to RF cable

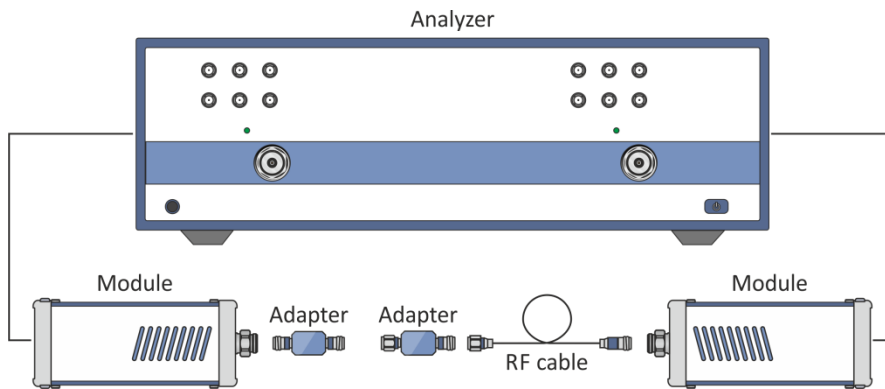
Figure 4.18 Full one-port calibration



Step 1: Full one-port calibration of port 1



Step 2: Full one-port calibration of port 2



Step 3: THRU measurement (in this example direct connection of test ports is used as flush thru with zero-length)

Figure 4.19 Full two-port SOLT calibration

Calibration is a method of controlling measurement accuracy. A judiciously chosen method is the key to controlling accuracy. There are two main calibration method families, called SOLT and TRL. The SOLT family applies calibration kits with fully known characteristics of standards. The TRL family uses calibration kits with partially known characteristics of standards. Depending on the calibration method family, calibration kits can contain several standards of one type, differing in connector type, frequency range, electrical length or other characteristics, or even no standards of any type.

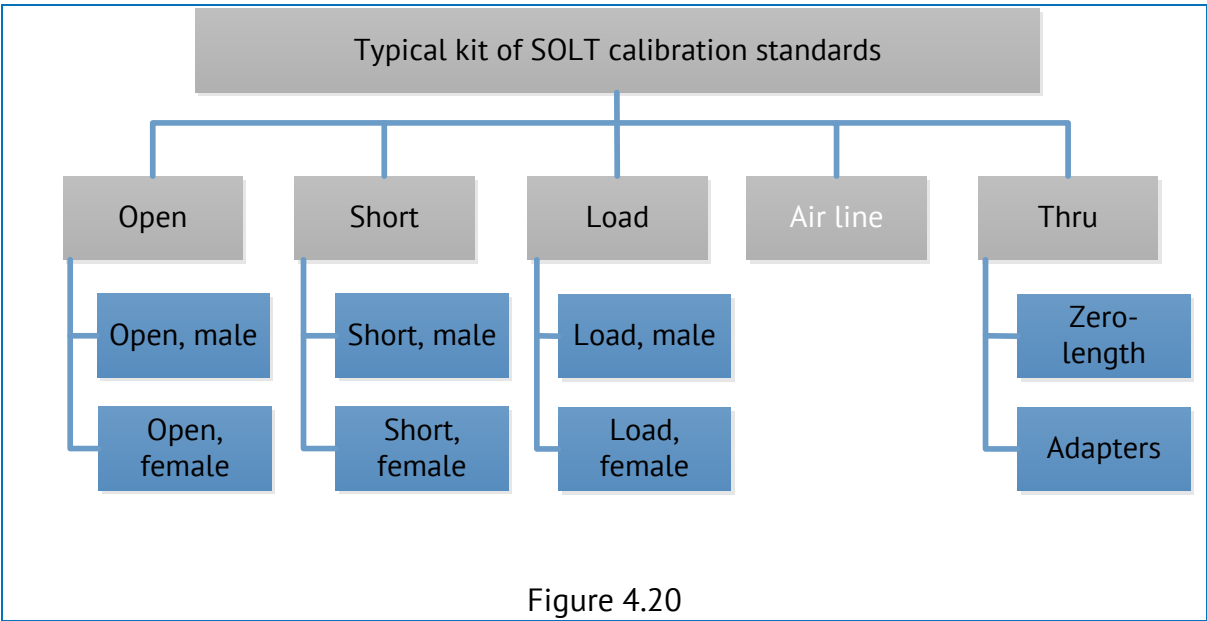


Figure 4.20

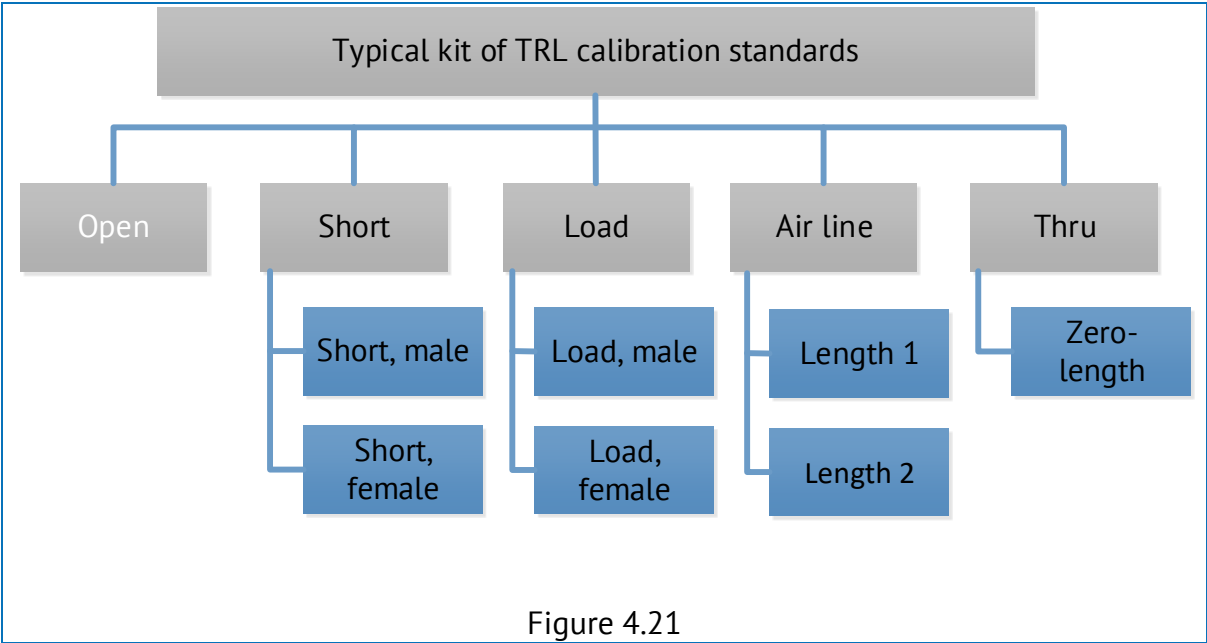


Figure 4.21

There are several steps of calibration. Certain standards are connected to test ports at each step. The calibration standards are divided into classes and subclasses so that they are not confused. Class is a conventional category intended to combine calibration standards into groups, which can be applied at the same step of calibration. Subclass is

a conventional category intended for arranging calibration standards within one class. The user can apply calibration kits the description of which is available in the software, or create new calibration kits. Calibration using a user-defined calibration kit is one of the convenient ways of performing calibration. In this case, the calibration kit is defined by the particular task and does not include rarely used standards.

4.3.5 Description of Basic Measurement Modes

Basic measurement modes
<u>S-parameters</u>
<u>Balanced measurements</u>
<u>Measurements in frequency offset mode</u>
<u>Time domain analysis and gating</u>

Typical measurement diagrams are shown in figures below. Test cables and adapters are not shown in the diagrams for simplicity.

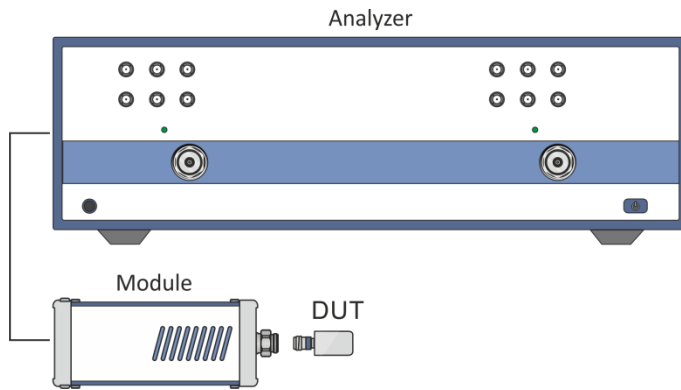
Test cables and adapters enable connection to DUT ports.

The usage of adapters increases the test ports' service life (test port connector located on the Module front panel and test cable connectors).



The quality of adapters has to be high enough to keep the measurement results repeatable at the proper level for a long period of time with multiple connections of DUTs. The repeatability should not exceed error margins for transmission and reflection coefficients measurements, otherwise the adapters and/or cables used should be replaced. It is recommended to use metrology-grade or instrument-grade adapters.

S-parameters

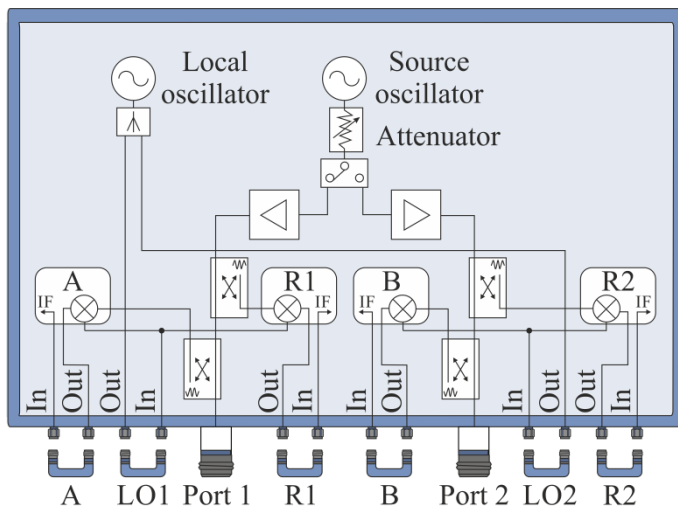


One-port DUT reflection coefficient

Available calibration methods (see section 4.3.4):

Reflection normalization

Full one-port calibration



Configurable panel (2 ports) for connecting frequency extension modules

Measurement

S-parameters

Format

Log. magnitude

Lin. magnitude

VSWR

Phase

Phase>180

Group delay

Real & Imaginary

Polar

Smith chart

Analysis

Electrical delay

Phase offset

Impedance conversion

S-parameter conversion (Z, Y, inverse S-parameters)

De-embedding

Embedding

Time domain

Functions

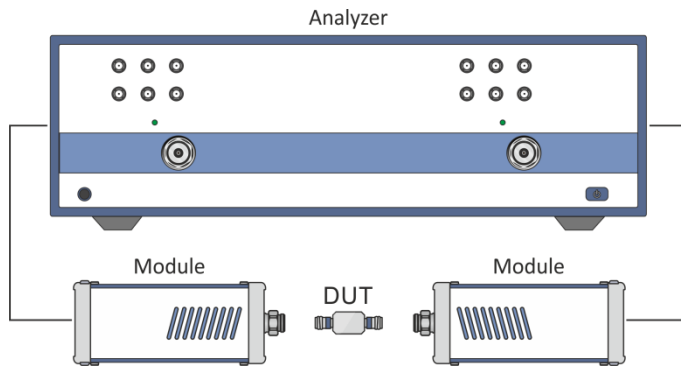
Statistics

Bandpass

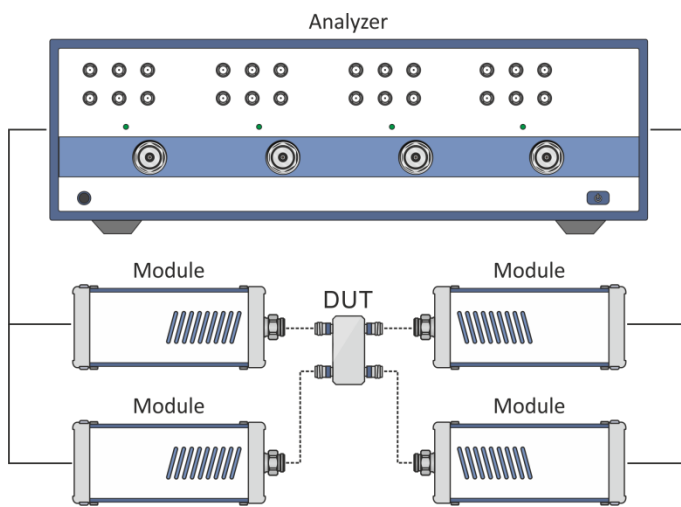
Flatness

Filter parameters

S-parameters



Simultaneous measurement of four S-parameters of a two-port DUT in one connection



16 S-parameters of a four-port DUT are measured using four modules in one connection

Available calibration methods (see section 4.3.4):

- Reflection normalization
- Full one-port calibration
- Transmission normalization
- One-path two-port calibration
- Full two/three/four-port calibration (SOLT)
- Two/three/four-port TRL calibration

Measurement

S-parameters

Format

- Log. magnitude
- Lin. magnitude
- VSWR
- Phase
- Phase>180
- Group delay
- Real & Imaginary
- Polar
- Smith chart

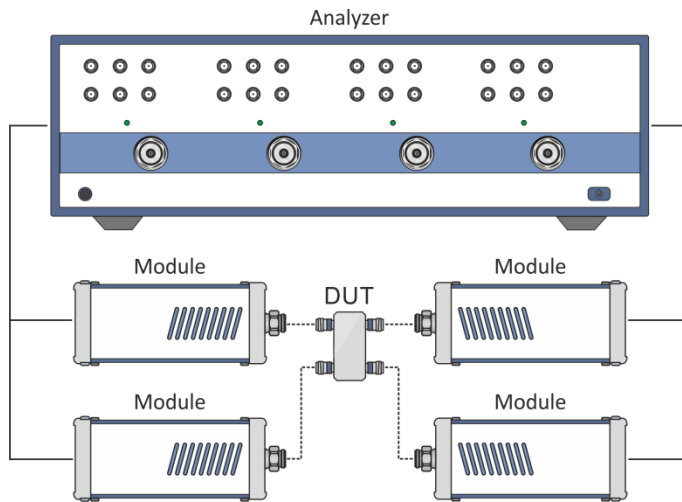
Analysis

- Electrical delay
- Phase offset
- Impedance conversion
- S-parameter conversion (Z, Y, inverse S-parameters)
- De-embedding
- Embedding
- Time domain

Functions

- Statistics
- Bandpass
- Flatness
- Filter parameters

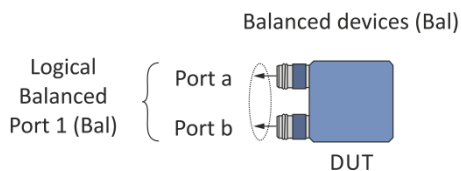
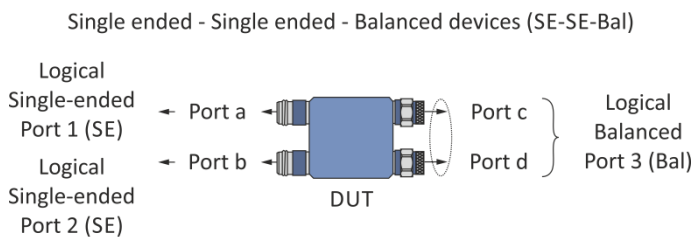
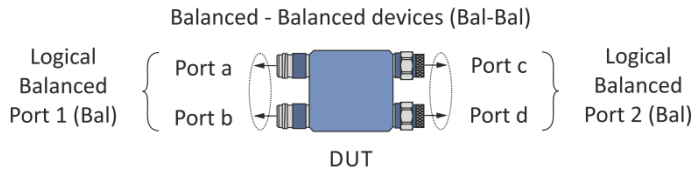
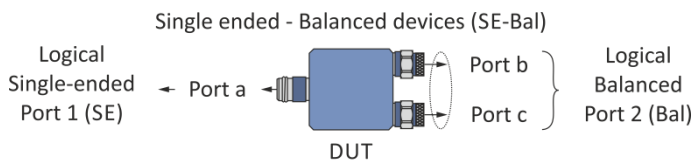
Balanced measurements



Measurement

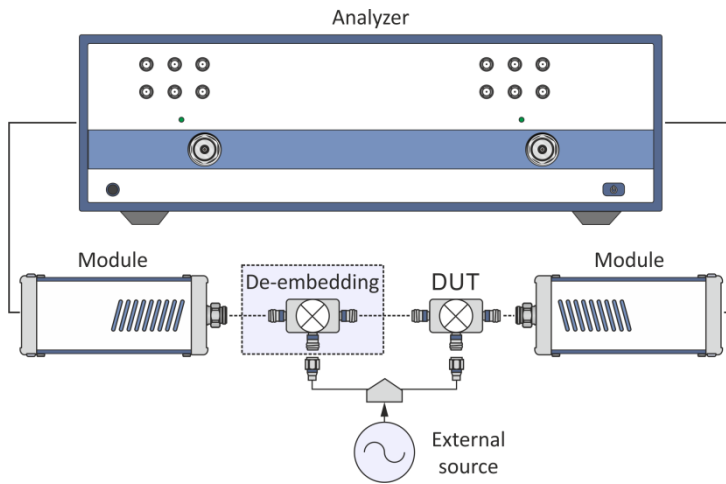
- S-parameters
- S-parameters in differential mode
- Common mode rejection ratio
- Disbalance

Measurement of DUTs parameters in differential mode

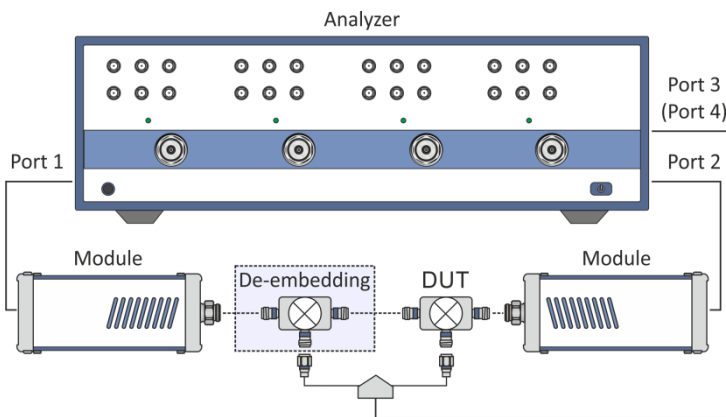


Types of balanced devices

Measurements in frequency offset mode



Mixer parameters measurement. An external signal source is used as an LO.



Mixer parameters measurement using a four-port analyzer and two modules

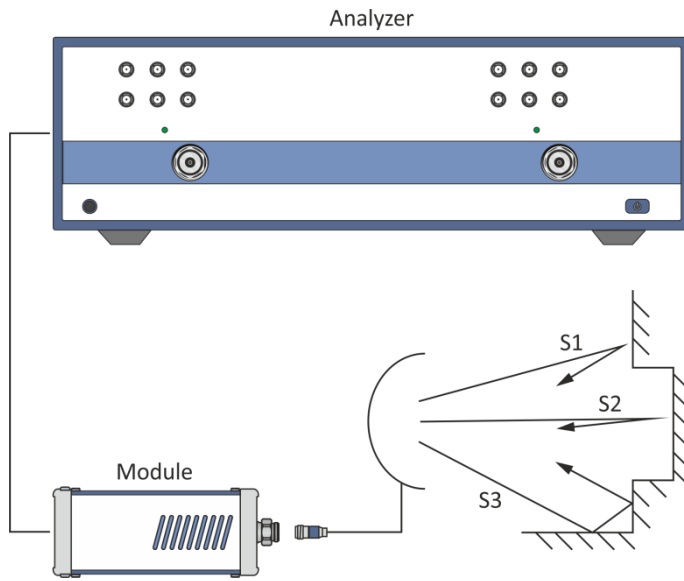
Measurement

S-parameters

Conversion coefficient

Group delay

Time domain



Time domain analysis with gating

Measurement

Z-transformation of frequency domain data multiplied by the window function in advance

Functions

Transformation type:

Bandpass mode

Lowpass mode

Gating

5 Storage instructions

Before first use, store Modules in the factory packaging at environment temperature from 0 to +40 °C and relative humidity up to 80% (at 25 °C).

After removing the factory packaging, store Modules at environment temperature from +10 to +35 °C and relative humidity up to 80% (at 25 °C).

Keep the storage facilities free from dust, acidic and alkali fumes, volatile gases, and other chemicals which can cause corrosion.

APPENDIX A
(REFERENCE)
CONNECTOR CARE INSTRUCTIONS

A.1 General Information

Please pay special attention to the quality of devices connected when operating at frequencies exceeding several dozens of Megahertz.

REGULARLY CHECK AND CLEAN THE CONNECTORS OF DEVICES USED.

DAMAGED OR DIRTY CONNECTORS CAN SIGNIFICANTLY IMPAIR MEASUREMENT RESULTS.

Surfaces of a connector's mating plane's outer conductors must be clean and smooth. The center conductor must have a certain pin depth (see A.3 for more information). Mating plane and conductor surfaces must be free from dents, deep scratches or worn plating.

NEVER USE DEVICES WITH CONNECTORS THAT HAVE MECHANICAL DAMAGE OR IMPROPER PIN DEPTH VALUE.

IT IS NECESSARY TO REGULARLY GAUGE THE CONNECTORS.

A user should gauge connectors before the first use of the device and regularly between uses.

It is recommended to gauge the connectors if:

- A visual inspection or measurement results suggest that the connector may have defects or damages;
- It is detected that the connectors of devices used with the Module are damaged or their pin depth values are out of range;
- After every 100 connections.

Connectors have limited operation time frames and can be damaged even if properly used. Regular checking and cleaning can extend this time limit:

- Cleaning procedure is described in section A.2;
- Connection sequence shown in section A.4 ensures maximum measurement results repeatability and connector damage prevention;
- When the devices (adapters, loads, standards) are continuously handled or their connectors are cleaned with compressed air, the housing temperature changes, and this can significantly affect electrical characteristics. In this case, wait until the temperature becomes stable before using the devices;
- Do not touch mating plane and conductor surfaces of connectors; fingerprints and microscopic particles are hard to remove and can impair measurement results;
- Put caps on connectors when they are not used;

- Use electrostatic discharge protection during measurements.

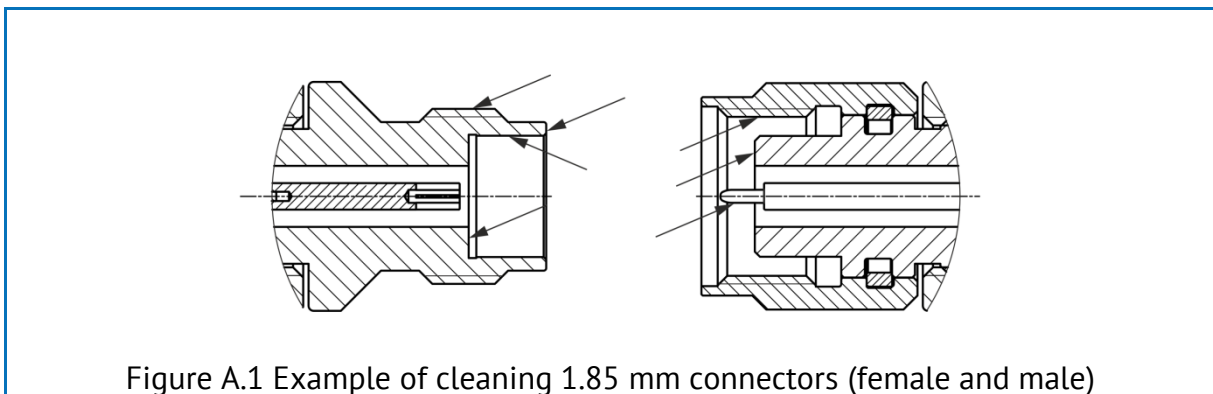
A.2 Cleaning Connectors

Clean connectors before and after using devices.

Device	Connector type
Frequency Extension Modules	NMD 1.85 mm, male (test port)
	SMA, female (RF, LO, IF ports)
Vector network analyzers	N, female (test port)
	SMA, female (configurable panel)
	NMD 3.5 mm, male (test port)
	3.5 mm, female (configurable panel)
Cables	N, male
	SMA, male

The procedure of cleaning coaxial connectors:

- Wipe the connector surfaces as shown in figure A.1 with a swab wetted in alcohol; alcohol drops should not get inside the devices or on the dielectric plate; the dielectric plate (SMS connectors) is cleaned with a dry swab or a dry lint-free cloth without applying pressure to the dielectric;



- Use compressed air to clean other internal connector surfaces;
- Let the alcohol dry on the connector surfaces;
- Visually inspect the connectors to make sure that no particles or residue remain;

- Repeat the cleaning procedure if necessary.



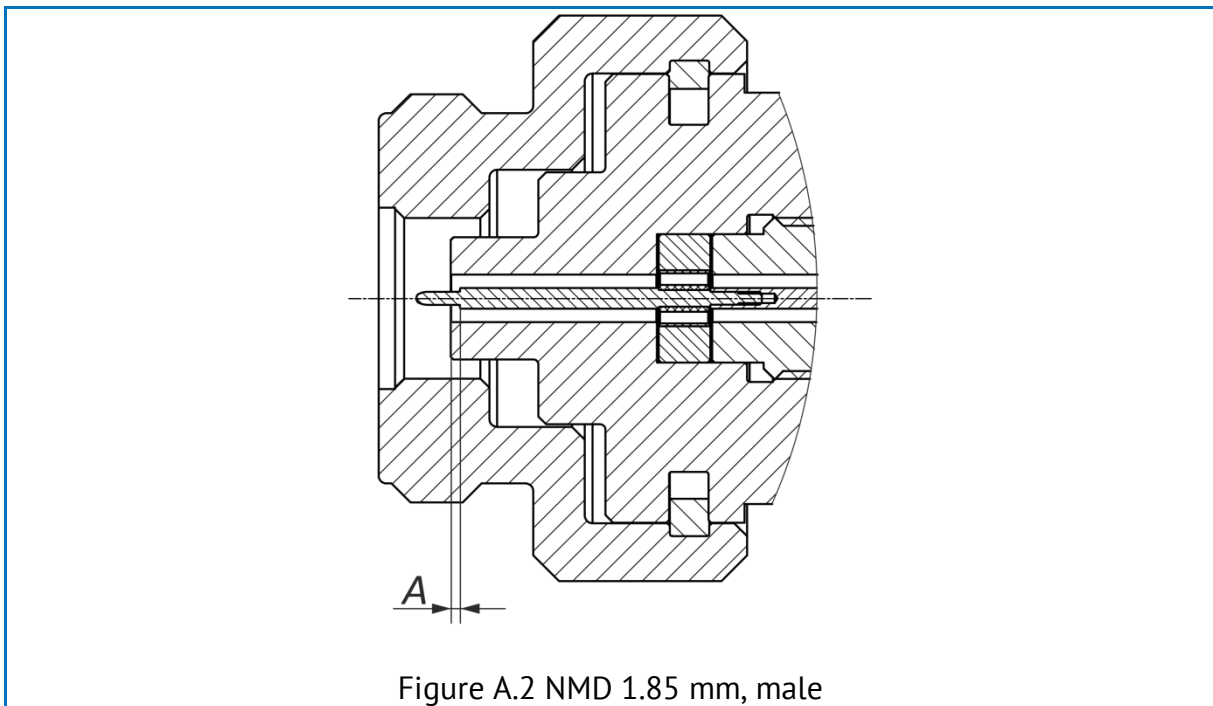
NEVER use metal items for cleaning connectors.

NEVER wipe the center conductors of female connectors. They should be blown with compressed air.

A.3 Gauging Connectors

Use gauges for coaxial connectors in compliance with their operating instructions or use multi-purpose tools for linear measurements (for example, micrometer, dial indicator, etc.) to gauge the connectors.

You need to measure only pin depth A during gauging (see figure A.2).



The pin depth value A of the test port must be within 0.00 to 0.08 mm.

A.4 Connecting and Disconnecting Devices

During operation, various devices need to be connected: cables to module ports, adapters to cables, calibration standards to adapters or module ports, DUTs to ports, etc.

Devices with coaxial connectors should be connected in the following order to ensure maximum measurement results, repeatability, and damage prevention:

- Carefully align the connectors;

- While holding the device being connected, tighten the connector nut finger tight. Mating plane surfaces of center conductors and outer conductors have to make contact as shown in figure A.3;

- Tighten the male connector nut using the appropriate torque wrench (the torque value depends on the connector type), while holding the device being connected by hand or an open-end wrench to keep it from turning. Finally tighten the male connector nut by holding the wrench at the end of the handle. Tighten the connection to the torque wrench “break” point.



Do not turn a device body. Only turn connector nuts.

Use a calibrated torque wrench with appropriate torque to tighten connector nuts.

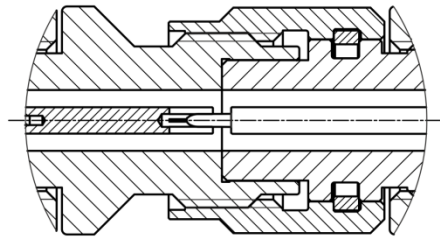


Figure A.3 Connection example
1.85 mm connectors (left - female, right - male)

Disconnect connectors in the following order:

- Using the torque wrench which was used for tightening, loosen the male connector nut while holding the device by hand or an open-end wrench to prevent it from turning;
- While holding the device so that the connector’s center conductor was at the same straight line as it was connected, turn the connector nut. Pull the connectors straight apart.