COPPER MOUNTAIN®
TECHNOLOGIES

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Automatic Calibration Module

Operating manual

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Introduction

Safety Instructions

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

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

WARNING

The Module should be used only by skilled and thoroughly trained personnel with the required skills and knowledge of safety precautions.

Connect the body of the controlling PC and the body of the VNA (the post marked ) to be used with the Module before starting operation.

Exceeding maximum input power of the RF signal or maximum DC voltage specified on the front panel of the Module can result in the Module breaking down.

Never operate the Module if the USB cable is damaged.

Protection from electrostatic discharge

Make sure to protect the work area from electrostatic discharge.

Electrostatic discharge can damage the Module when connected or disconnected from the VNA, during the connectors cleaning, or during visual inspection.

WARNING

Static charge can build up on the body and damage the sensitive circuits of internal components of both the Module and the VNA being calibrated. To avoid damage from electric discharge, observe the following:

- Always discharge the static charge accumulated on the body before touching the Module or any other sensitive to static electricity devices.
- 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 1MΩ resistor.

Definitions of safety symbols used on the instrument and in the manual are listed below.

WARNING	This sign denotes a hazard. It calls attention to a procedure, practice, or condition that, if not correctly performed or adhered to, could result in injury or death to personnel.
CAUTION	This sign denotes a hazard. It calls attention to a procedure, practice, or condition that, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the instrument.
NOTE	This sign denotes important information. It calls attention to a procedure, practice, or condition that is essential for the user to understand.

General Overview

The Module is designed for calibration (error correction) of Vector Network Analyzers in automatic mode.

Calibration is performed by automatically connecting the reflection and transmission impedance states to the VNA test ports.

Calibration determines systematic errors in accordance with the VNA model. The process of mathematical compensation (numerical reduction) for measurement systematic errors is called error correction.

Using the Module instead of a mechanical calibration kit has several advantages, which ensure high measurement accuracy and a longer service life of the VNA test ports. The measurement accuracy is achieved using precision Module standards (states) descriptions, by the stability of the selected configuration, and by the application of temperature drift functions and self-diagnosis in the form of confidence check. Single module connection during calibration allows to:

- Extend the VNA ports service life.
- Reduce technical staff workload and risk of human error.
- Make the measurement process most efficient.

The Module control protocol is based on the USBTMC-USB488 standard.

Modification

The Module differ in operating frequency range and in the number of ports. Their functional features are briefly described in the table below and in Appendix A.

During calibration, the Modules are controlled by the VNA software installed on the connected PC. The USB 2.0 interface is used for control.

The Modules feature several hardware configurations depending on the connector types of PORT A, PORT B and, if available, PORT C and PORT D. To view the possible connector type front and side views for each Module, click on the name of the desired Module in the table below.

The Module delivery package is specified in Delivery Kit.

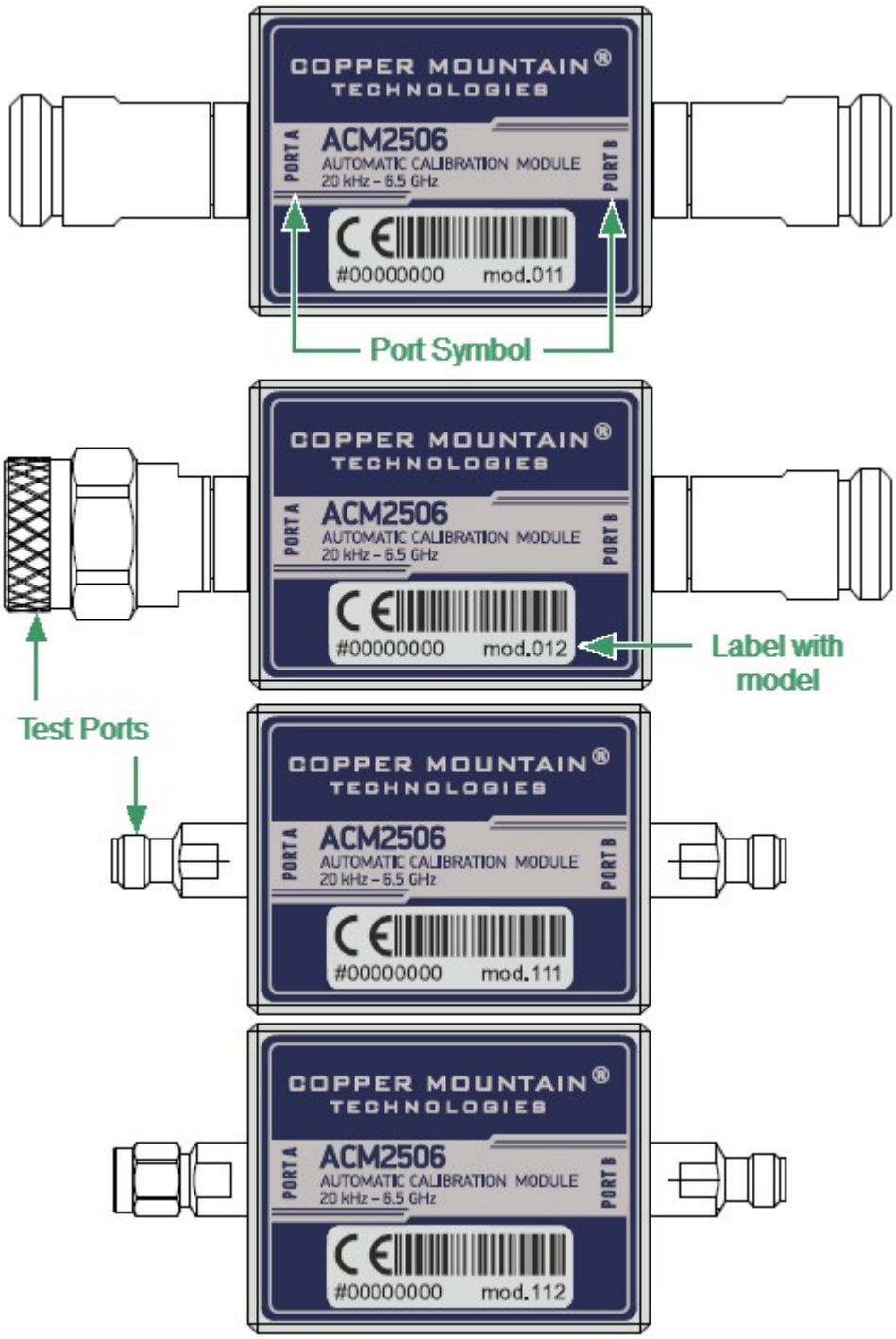
Functional Features

Module	Frequency range
50 Ohm two-port Modules	
ACM2506	20 kHz to 6.5 GHz
ACM2509	20 kHz to 9 GHz
ACM2520	100 kHz to 20 GHz
ACM2543	10 MHz to 44 GHz
ACM6000T	20 kHz to 6 GHz
ACM8000T	100 kHz to 8 GHz
75 Ohm two-port Modules	
ACM2708	20 kHz to 8 GHz
ACM4000T	20 kHz to 4 GHz
50 Ohm four-port Modules	
ACM4509	100 kHz to 9 GHz

Module	Frequency range
ACM4520	100 kHz to 20 GHz
ACM8400T	100 kHz to 8 GHz
1 The upper frequency point of ACM2520 and ACM4520 with type N connectors is 18 GHz. 2 The upper frequency point of ACM2543 with 2.92 mm connectors is 40 GHz.	

ACM2506

The front panels of the different models of ACM2506 are shown in the figure below.



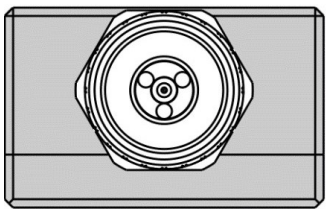
Front panel ACM2506

Parts of the ACM2509

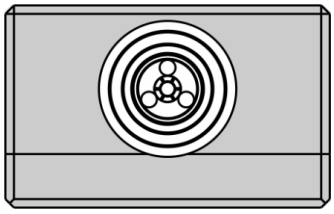
Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports.

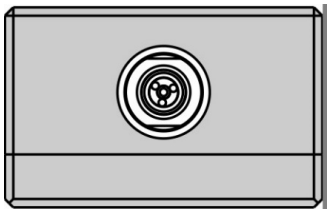
The Modules connectors are shown in figures below.



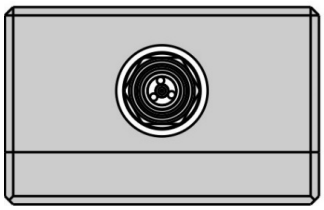
Type N, male



Type N, female

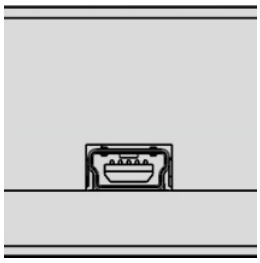


3.5 mm, male



3.5 mm, female

Mini USB Connector (on side panel)



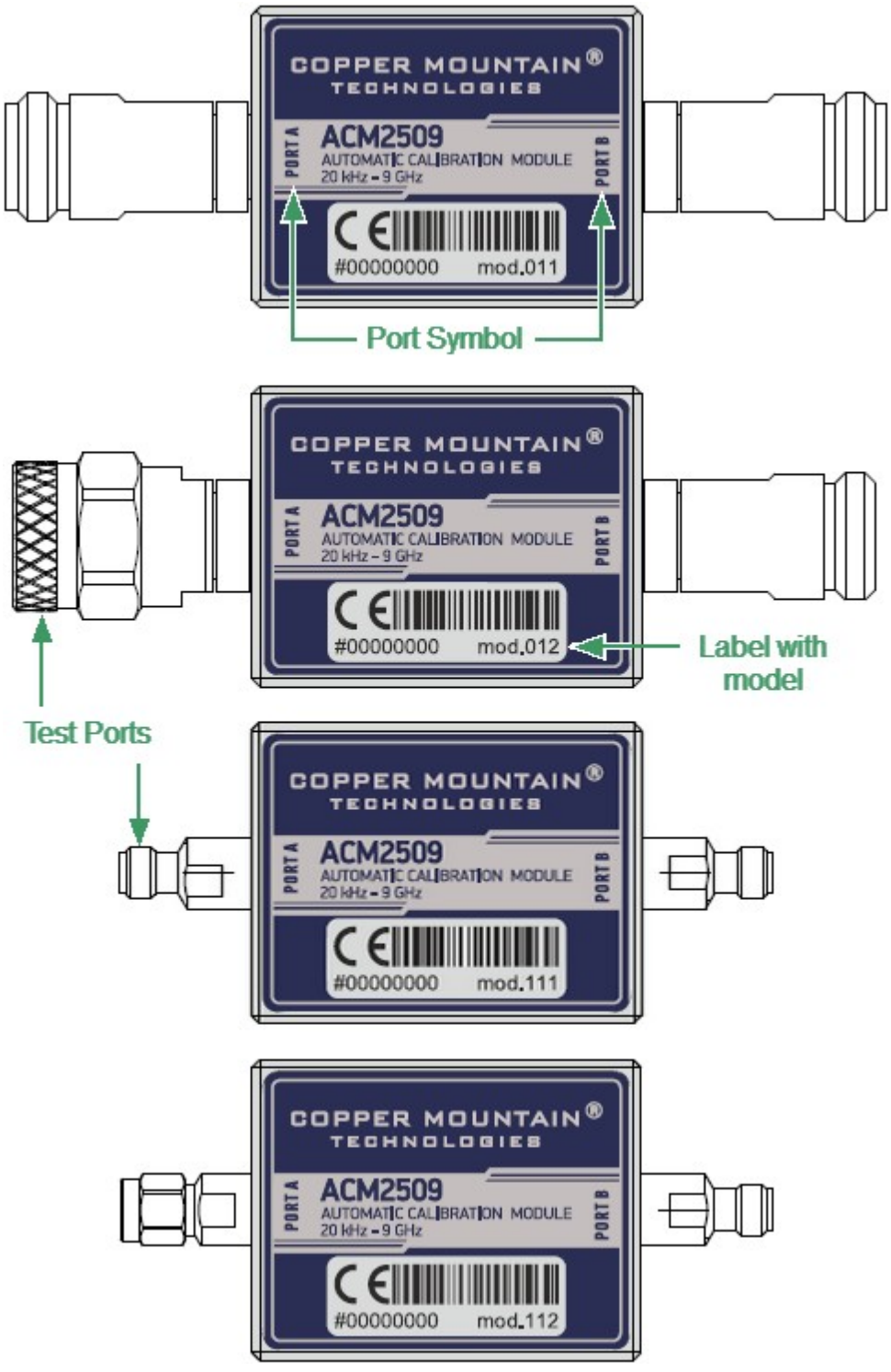
The mini USB connector is located at the side panel of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

Hardware configurations

Model	Connector type	
	Port A	Port B
ACM2506-011	type N, female	type N, female
ACM2506-012	type N, male	type N, female
ACM2506-111	3.5 mm, female	3.5 mm, female
ACM2506-112	3.5 mm, male	3.5 mm, female

ACM2509

Front panel of different models of ACM2506 are shown in figure below.



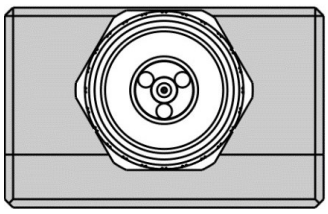
Front panel ACM2509

Parts of Module

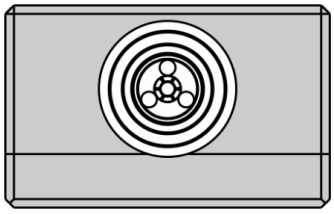
Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports.

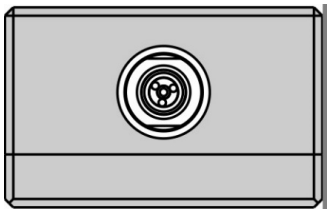
The Modules connectors are shown in figures below.



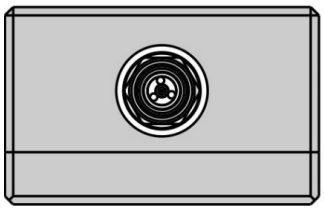
Type N, male



Type N, female

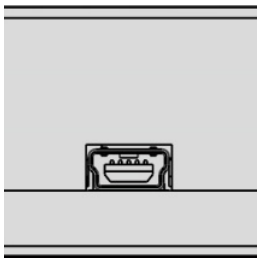


3.5 mm, female



3.5 mm, male

Mini USB Connector (on side panel)



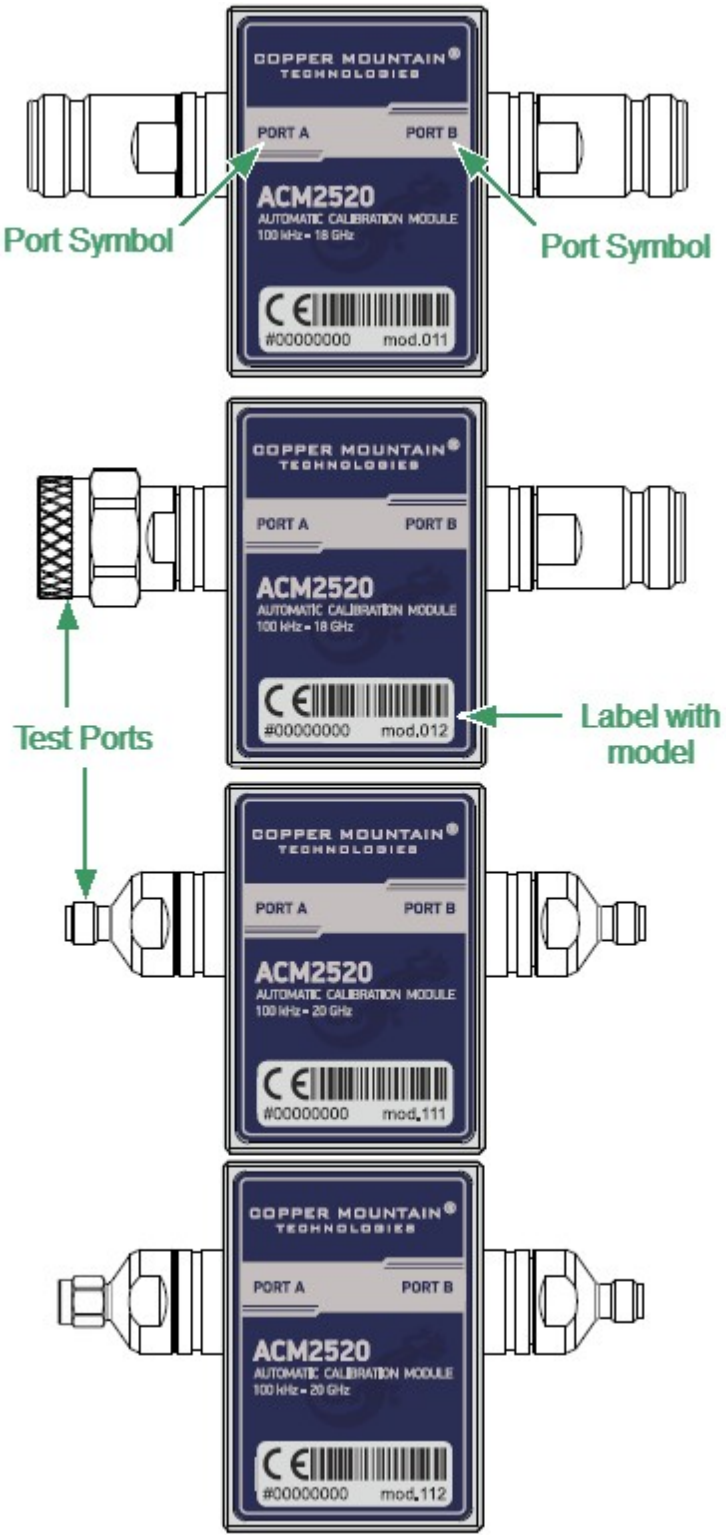
The mini USB connector is located on the side panel of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

Hardware configurations

Model	Connector type	
	Port A	Port B
ACM2509-011	type N, female	type N, female
ACM2509-012	type N, male	type N, female
ACM2509-111	3.5 mm, female	3.5 mm, female
ACM2509-112	3.5 mm, male	3.5 mm, female

ACM2520

The front panels of the different models of ACM2520 are shown in the figure below.



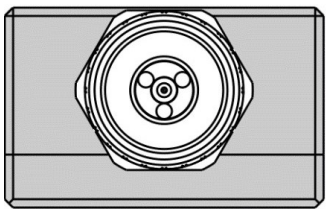
Front panel ACM2520

Parts of Module

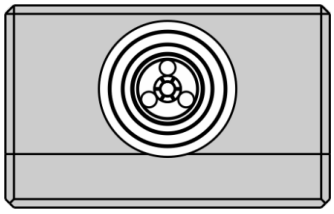
Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports.

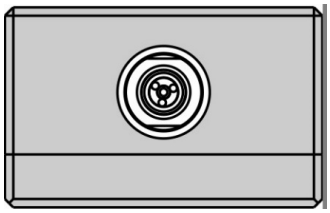
The Modules connectors are shown in figures below.



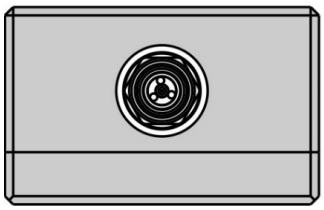
Type N, male



Type N, female

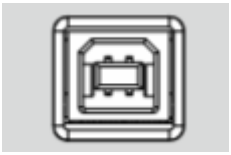


3.5 mm, female



3.5 mm, male

Connector (on side panel)



The connector is located on the top of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

LED Status Indicator (on rear panel)

NOTE	LED Status Indicator is located under the label and is visible only during operation.

The LED indicates the following statuses:

- Blinking green and red LED mean testing LED and indicating external power supply voltage presence.

- Red LED indicator means warm-up mode of the Module. The time required for operating mode setting is automatically counted from the moment of the Module connection using USB. If the Module is disconnected during setting and reconnected again, then the countdown counter starts from the beginning.

  Additional red LED may indicate the Module connection loss with the PC. In this case, check the Module connection with software (the **Autocalibration** softkey should be active), if there is no connection, disconnect the USB cable from the Module and repeat the connection.

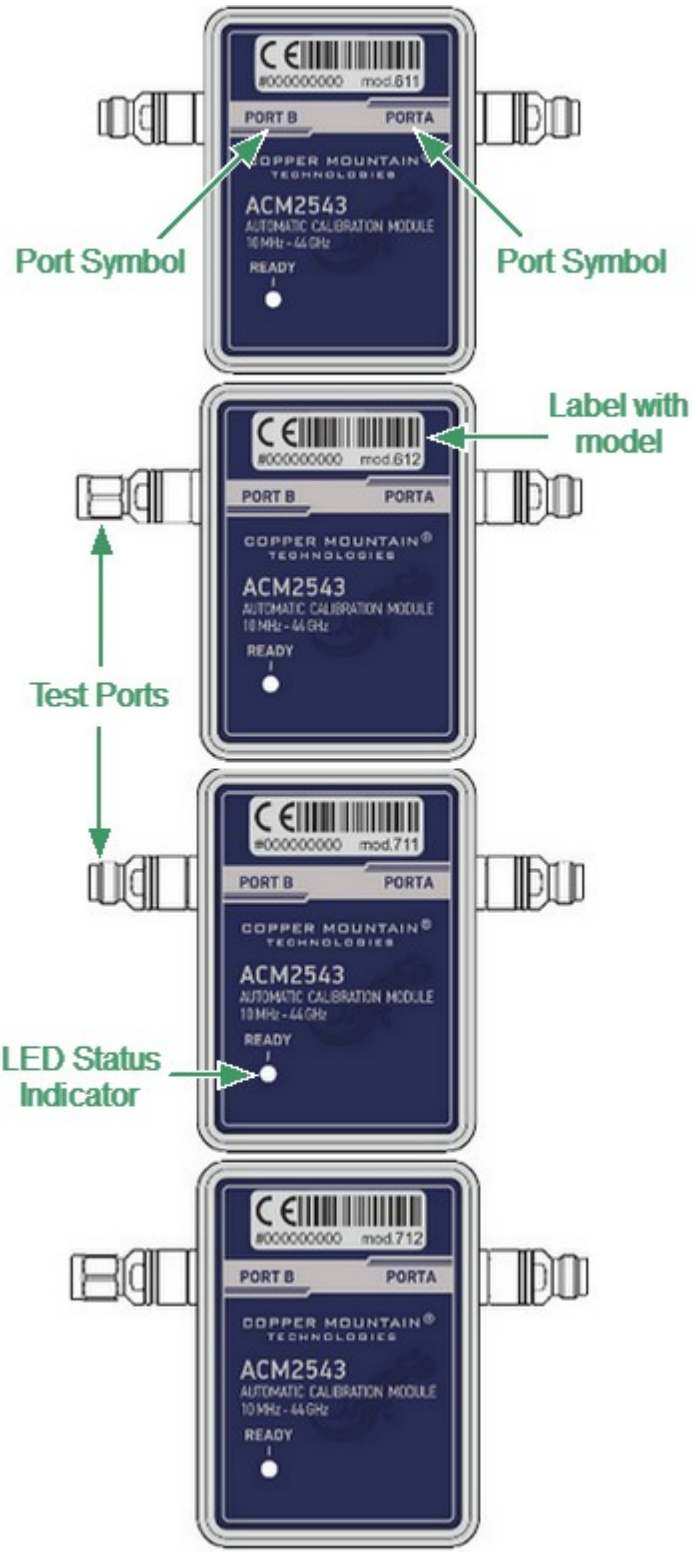
- Green LED indicator means the Module is ready for operation.

Hardware configurations

Model	Connector type	
	Port A	Port B
ACM2520-011	type N, female	type N, female
ACM2520-012	type N, male	type N, female
ACM2520-111	3.5 mm, female	3.5 mm, female
ACM2520-112	3.5 mm, male	3.5 mm, female

ACM2543

The rear panels of the different models of ACM2543 are shown in the figure below.

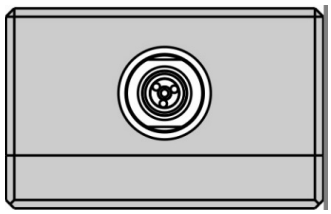


Rear panel ACM2543

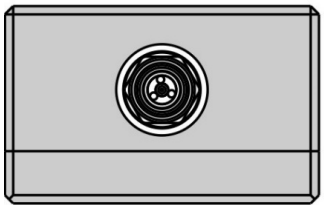
Parts of Module

Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports. The Modules connectors are shown in figures below.



2.4 mm (2.92 mm), female



2.4 mm (2.92 mm), male

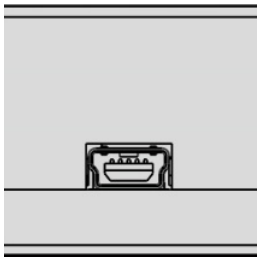
LED Status Indicator

The LED indicates the following statuses:

- Blinking green and red LED mean testing LED and indicating external power supply voltage presence.
- Red LED indicator means warm-up mode of the Module. The time required for operating mode setting is automatically counted from the moment of the Module connection using USB. If the Module is disconnected during setting and reconnected again, then the countdown counter starts from the beginning.

  Additional red LED may indicate the Module connection loss with the PC. In this case, check the Module connection with software (the **Autocalibration** softkey should be active), if there is no connection, disconnect the USB cable from the Module and repeat the connection.
- Green LED indicator means the Module is ready for operation.

Mini USB Connector (on side panel)



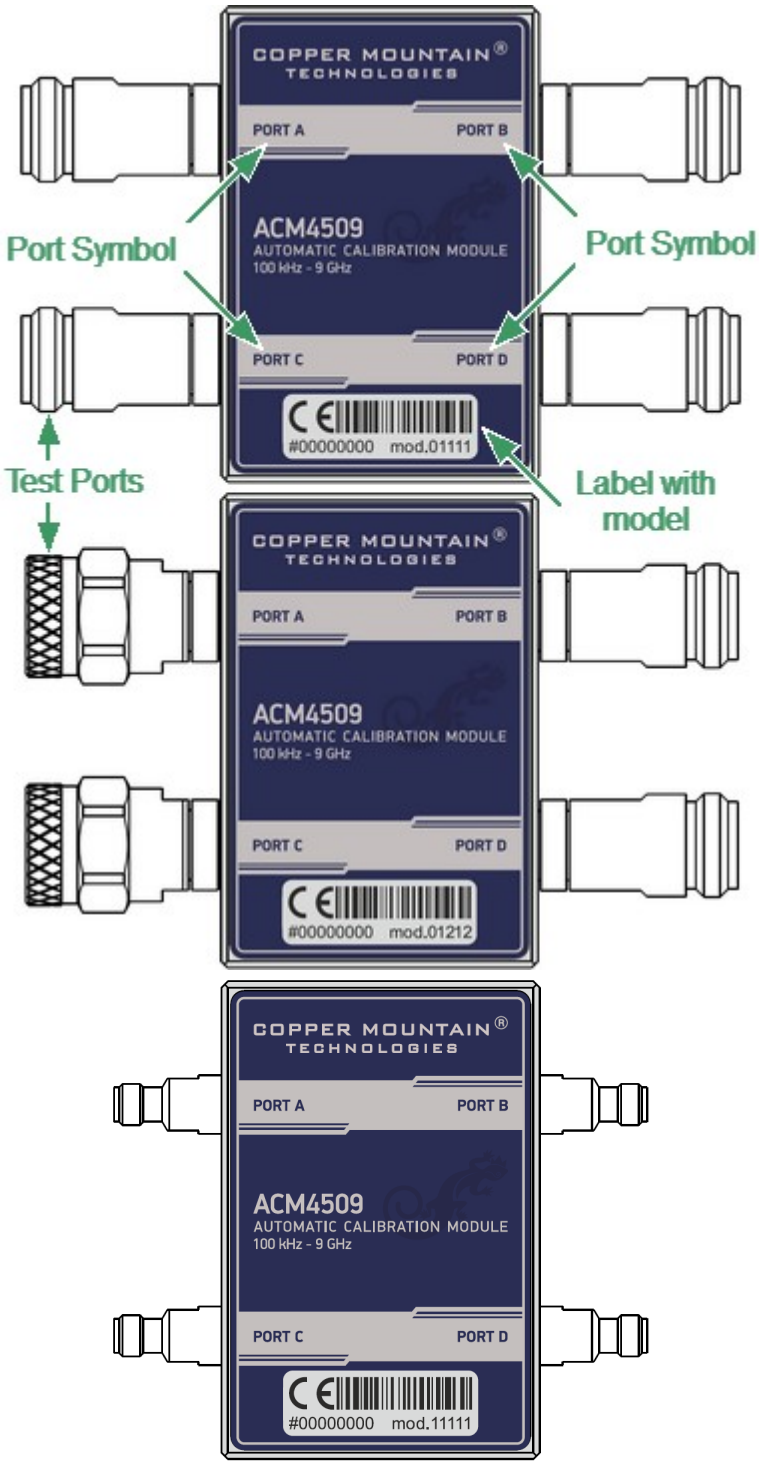
The connector is located on the top of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

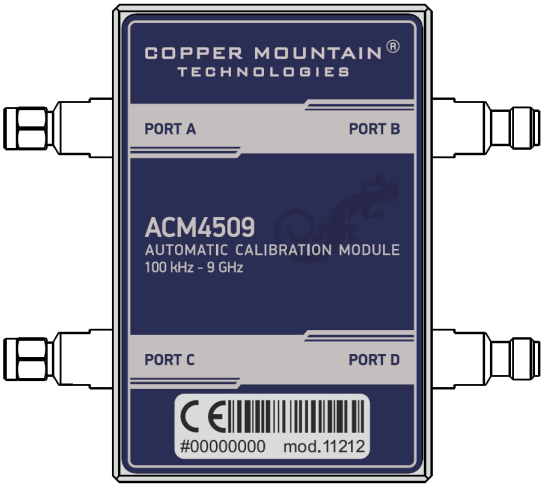
Hardware configurations

Model	Connector type	
	Port A	Port B
ACM2543-611	2.92 mm, female	2.92 mm, female
ACM2543-612	2.92 mm, male	2.92 mm, female
ACM2543-711	2.4 mm, female	2.4 mm, female
ACM2543-712	2.4 mm, male	2.4 mm, female

ACM4509

The front panels of the different models of ACM4509 are shown in the figure below.





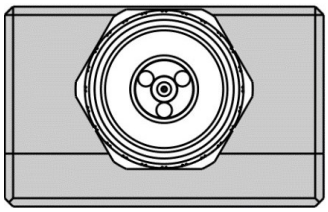
Front panel ACM4509

Parts of Module

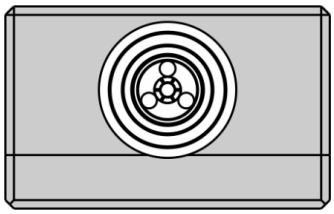
Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports.

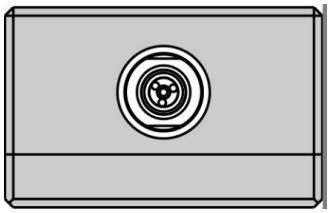
The Modules connectors are shown in figures below.



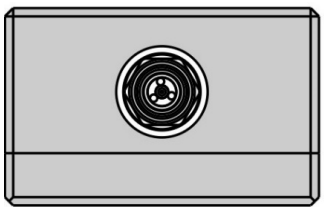
Type N, male



Type N, female

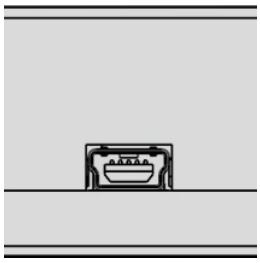


3.5 mm, female



3.5 mm, male

Mini USB Connector (on side panel)



The mini USB connector is located on the bottom of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

LED Status Indicator (on rear panel)

NOTE LED Status Indicator is located under the label and is visible only during operation.

The LED indicates the following statuses:

- Blinking green and red LED mean testing LED and indicating external power supply voltage presence.
- Red LED indicator means warm-up mode of the Module. The time required for operating mode setting is automatically counted from the moment of the Module connection using USB. If the Module is disconnected during setting and reconnected again, then the countdown counter starts from the beginning.

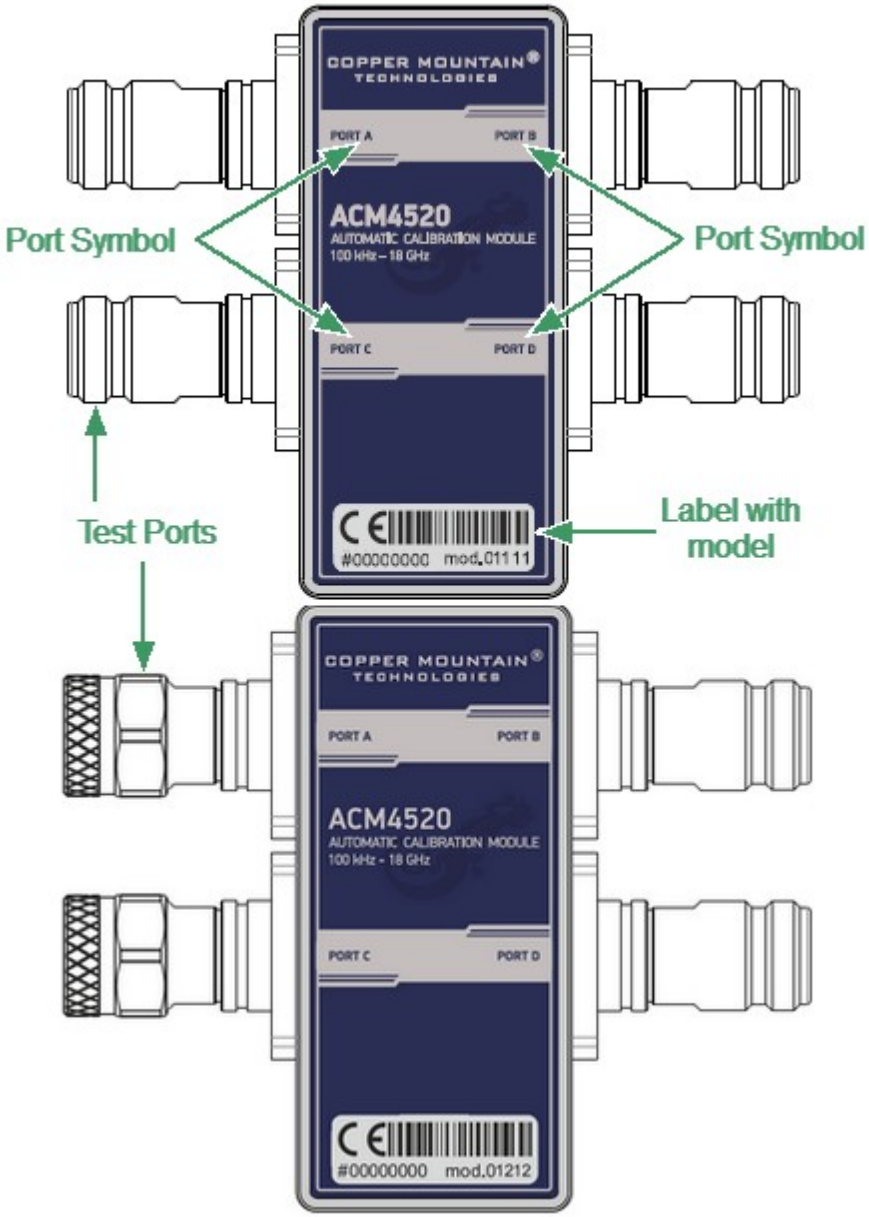
  Additional red LED may indicate the Module connection loss with the PC. In this case, check the Module connection with software (the **Autocalibration** softkey should be active), if there is no connection, disconnect the USB cable from the Module and repeat the connection.
- Green LED indicator means the Module is ready for operation.

Hardware configurations

Model	Connector type	
	Port A/C	Port B/D
ACM4509-01111	type N, female	type N, female
ACM4509-01212	type N, male	type N, female
ACM509-11111	3.5 mm, female	3.5 mm, female
ACM4509-11212	3.5 mm, male	3.5 mm, female

ACM4520

The front panels of the different models of ACM4520 are shown in the figure below.



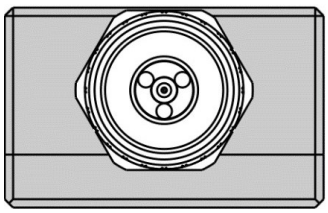
Front panel ACM4520

Parts of Module

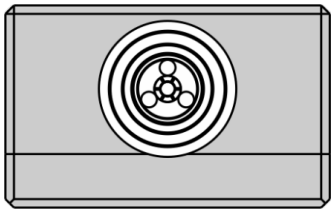
Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports.

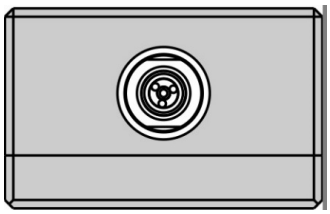
The Modules connectors are shown in figures below.



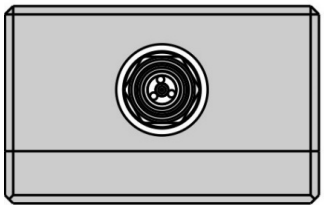
Type N, male



Type N, female



3.5 mm, female



3.5 mm, male

Connector (on side panel)

The connector is located on the bottom of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

LED Status Indicator (on rear panel)

NOTE	LED Status Indicator is located under the label and is visible only during operation.

The LED indicates the following statuses:

- Blinking green and red LED mean testing LED and indicating external power supply voltage presence.
- Red LED indicator means warm-up mode of the Module. The time required for operating mode setting is automatically counted from the moment of the Module connection using USB. If the Module is disconnected during setting and reconnected again, then the countdown counter starts from the beginning.

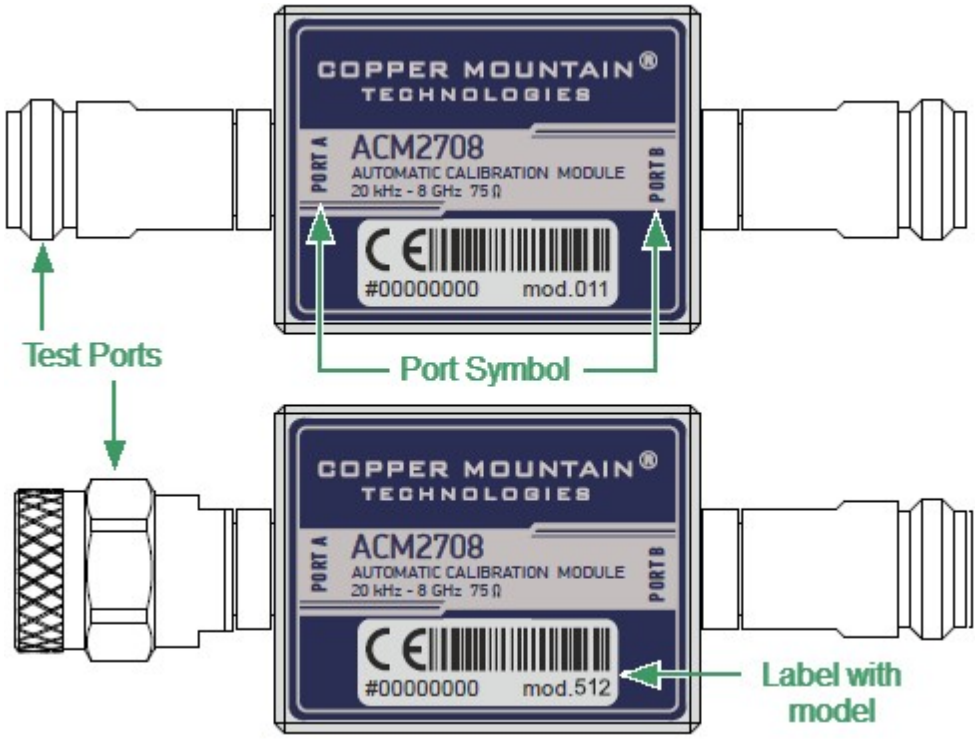
  Additional red LED may indicate the Module connection loss with the PC. In this case, check the Module connection with software (the **Autocalibration** softkey should be active), if there is no connection, disconnect the USB cable from the Module and repeat the connection.
- Green LED indicator means the Module is ready for operation.

Hardware configurations

Model	Connector type	
	Port A/C	Port B/D
ACM4520-01111	type N, female	type N, female
ACM4520-01212	type N, male	type N, female
ACM4520-11111	3.5 mm, female	3.5 mm, female
ACM4520-11212	3.5 mm, male	3.5 mm, female

ACM2708

The front panels of the different models of ACM2708 are shown in the figure below.



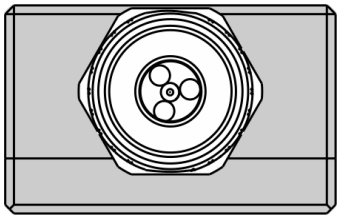
Front panel ACM2708

Parts of Module

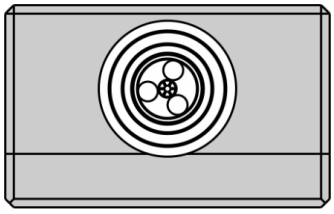
Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports.

The Modules connectors are shown in figures below.

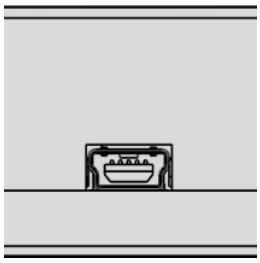


Type N 75, male



Type N 75, female

Connector (on side panel)



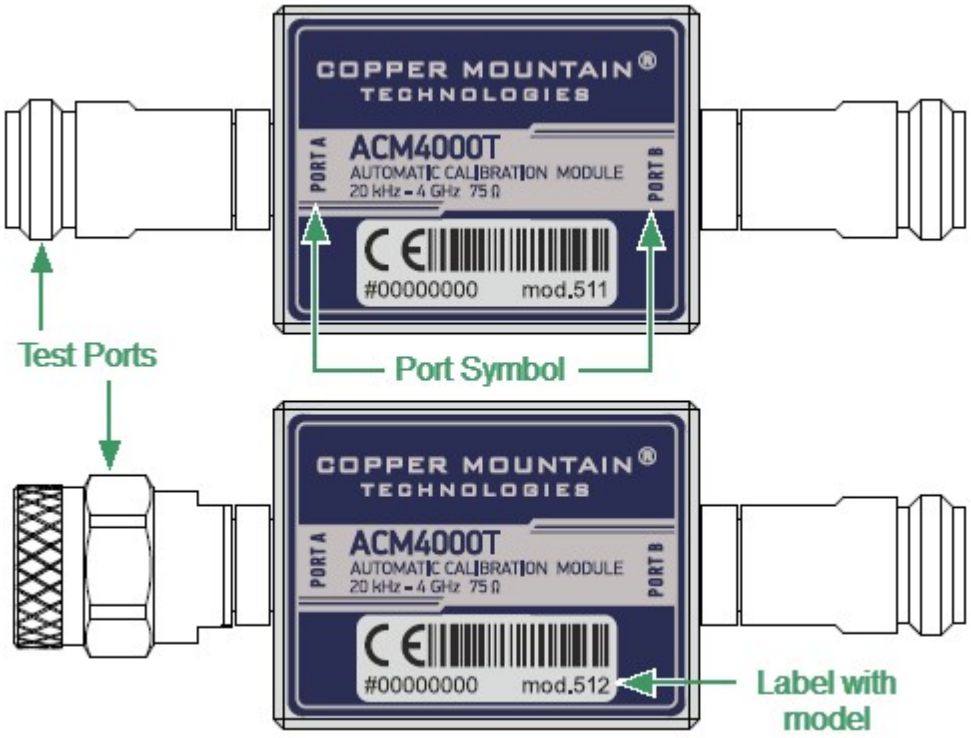
The connector is located on the bottom of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

Hardware configurations

Model	Connector type	
	Port A	Port B
ACM2708-511	type N 75, female	type N 75, female
ACM2708-512	type N 75, male	type N 75, female

ACM4000T

The front panels of the different models of ACM4000T are shown in the figure below.



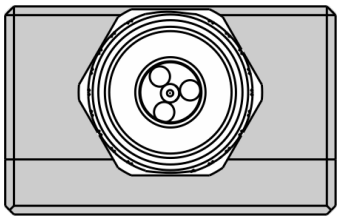
Front panel ACM4000T

Parts of Module

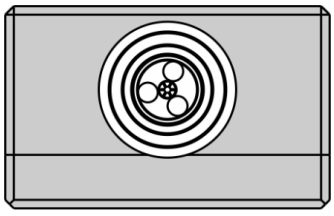
Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports.

The Modules connectors are shown in figures below.

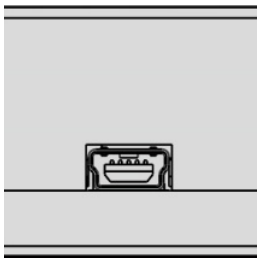


Type N 75, male



Type N 75, female

Connector (on side panel)



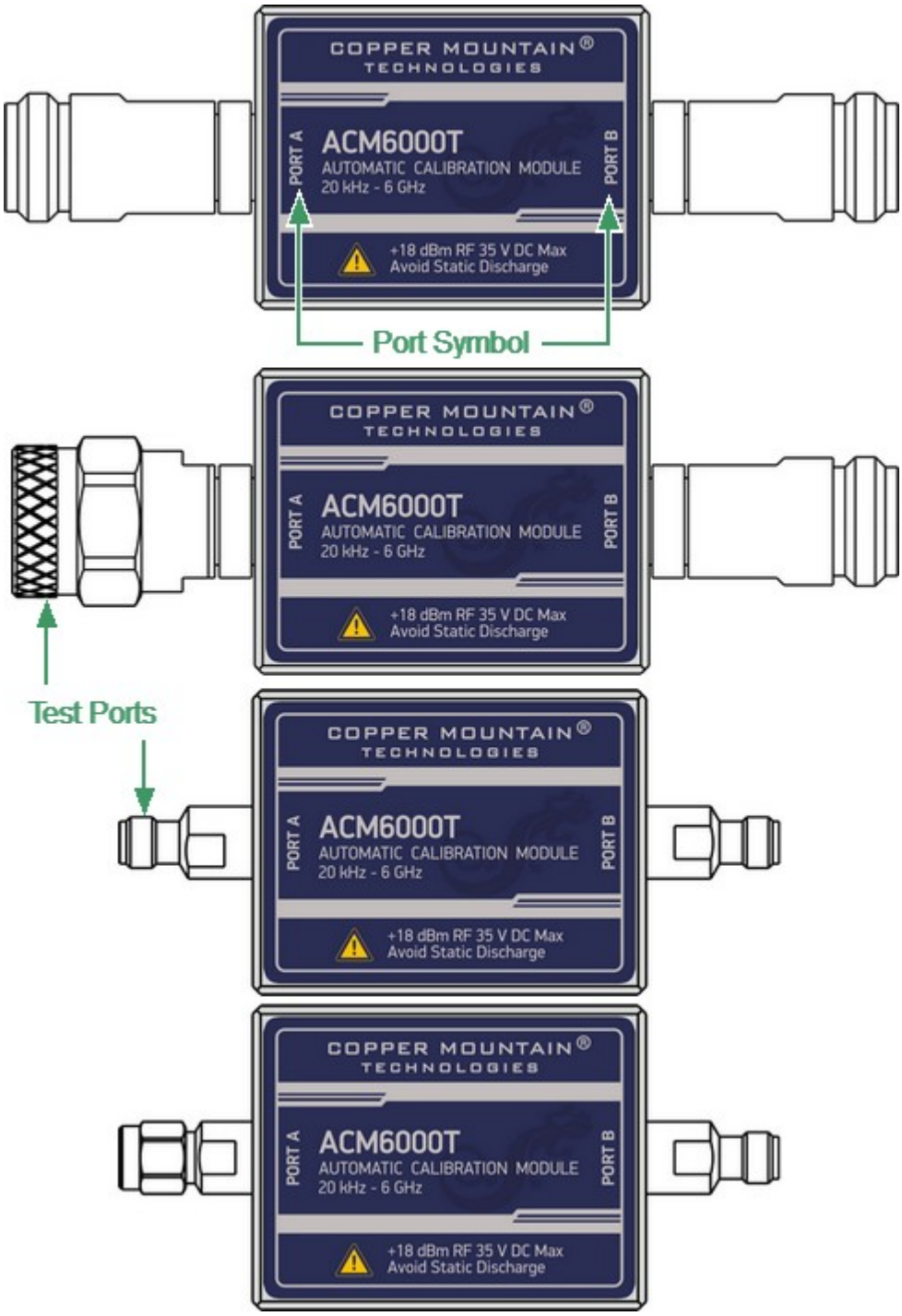
The connector is located on the bottom of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

Hardware configurations

Model	Connector type	
	Port A	Port B
ACM4000T-511	type N 75, female	type N 75, female
ACM4000T-512	type N 75, male	type N 75, female

ACM6000T

The front panels of the different models of ACM6000T are shown in the figure below.



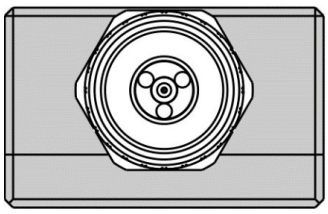
Front panel ACM6000T

Parts of Module

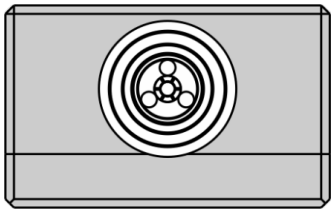
Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports.

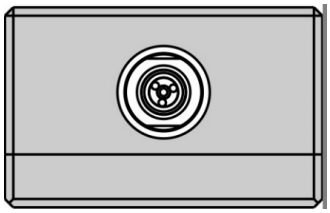
The Modules connectors are shown in figures below.



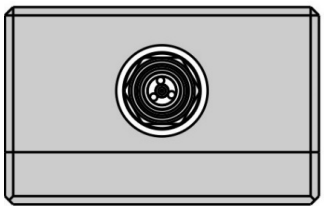
Type N, male



Type N, female

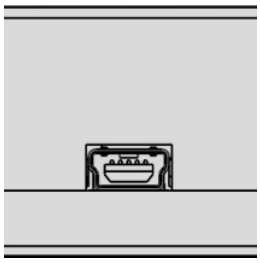


3.5 mm, female



3.5 mm, male

Connector (on side panel)



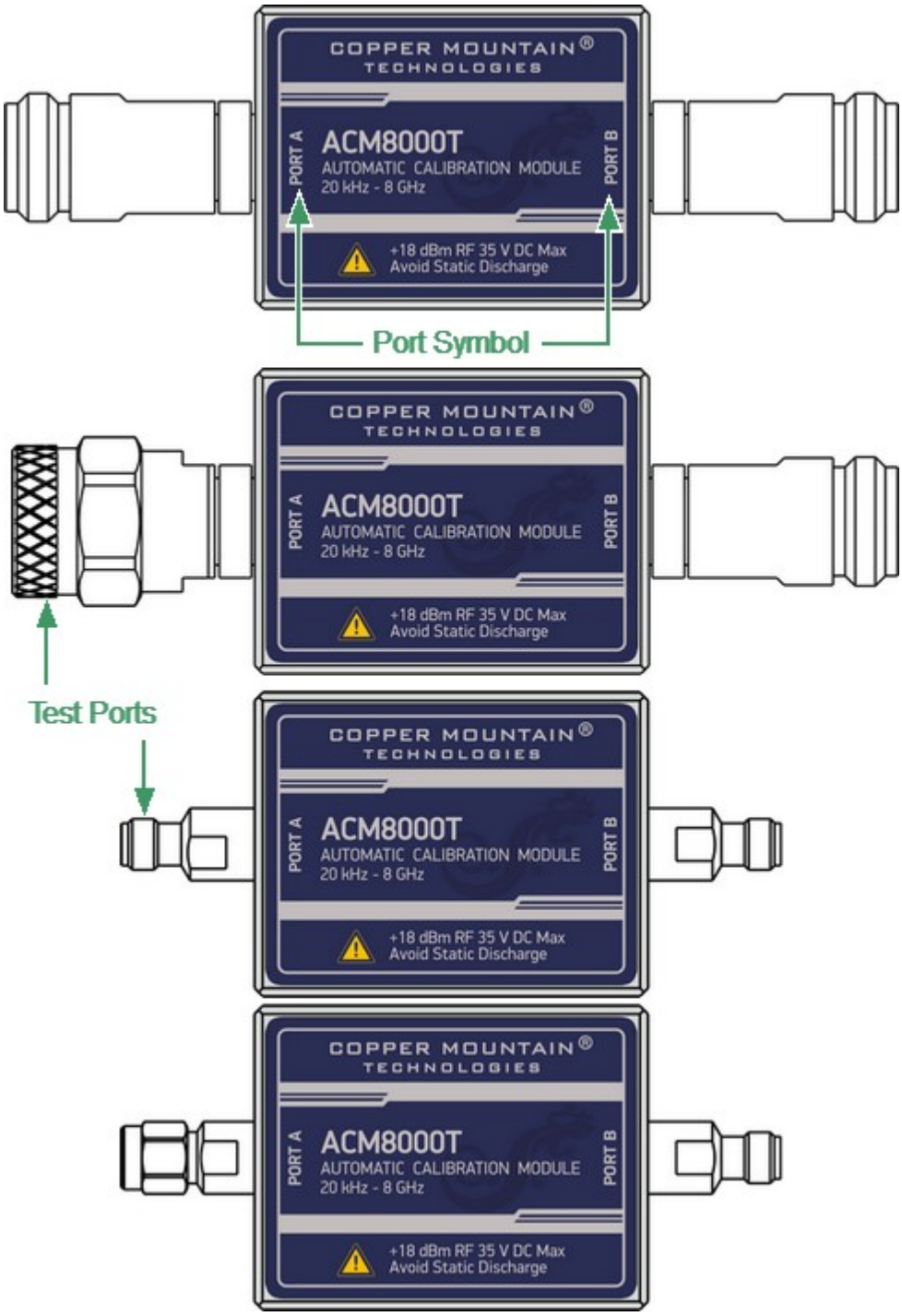
The connector is located on the bottom of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

Hardware configurations

Model	Connector type	
	Port A	Port B
ACM6000T-011	type N, female	type N, female
ACM6000T-012	type N, male	type N, female
ACM6000T-111	3.5 mm, female	3.5 mm, female
ACM6000T-112	3.5 mm, male	3.5 mm, female

ACM8000T

The front panels of the different models of ACM8000T are shown in the figure below.



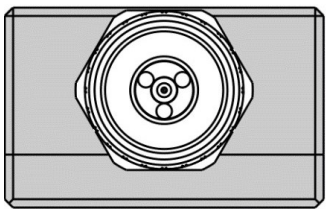
Front panel ACM8000T

Parts of Module

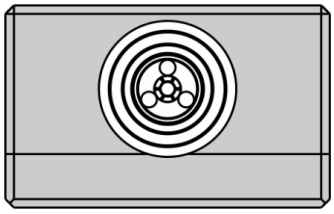
Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports.

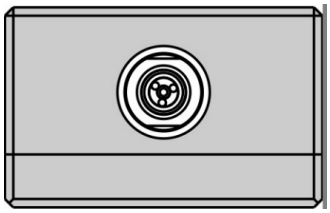
The Modules connectors are shown in figures below.



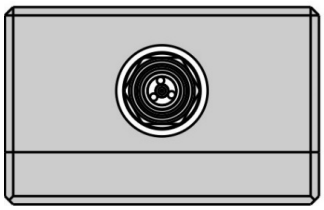
Type N, male



Type N, female

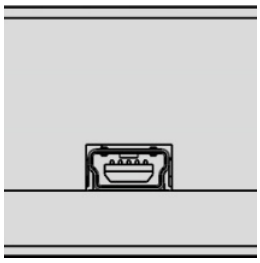


3.5 mm, female



3.5 mm, male

Connector (on side panel)



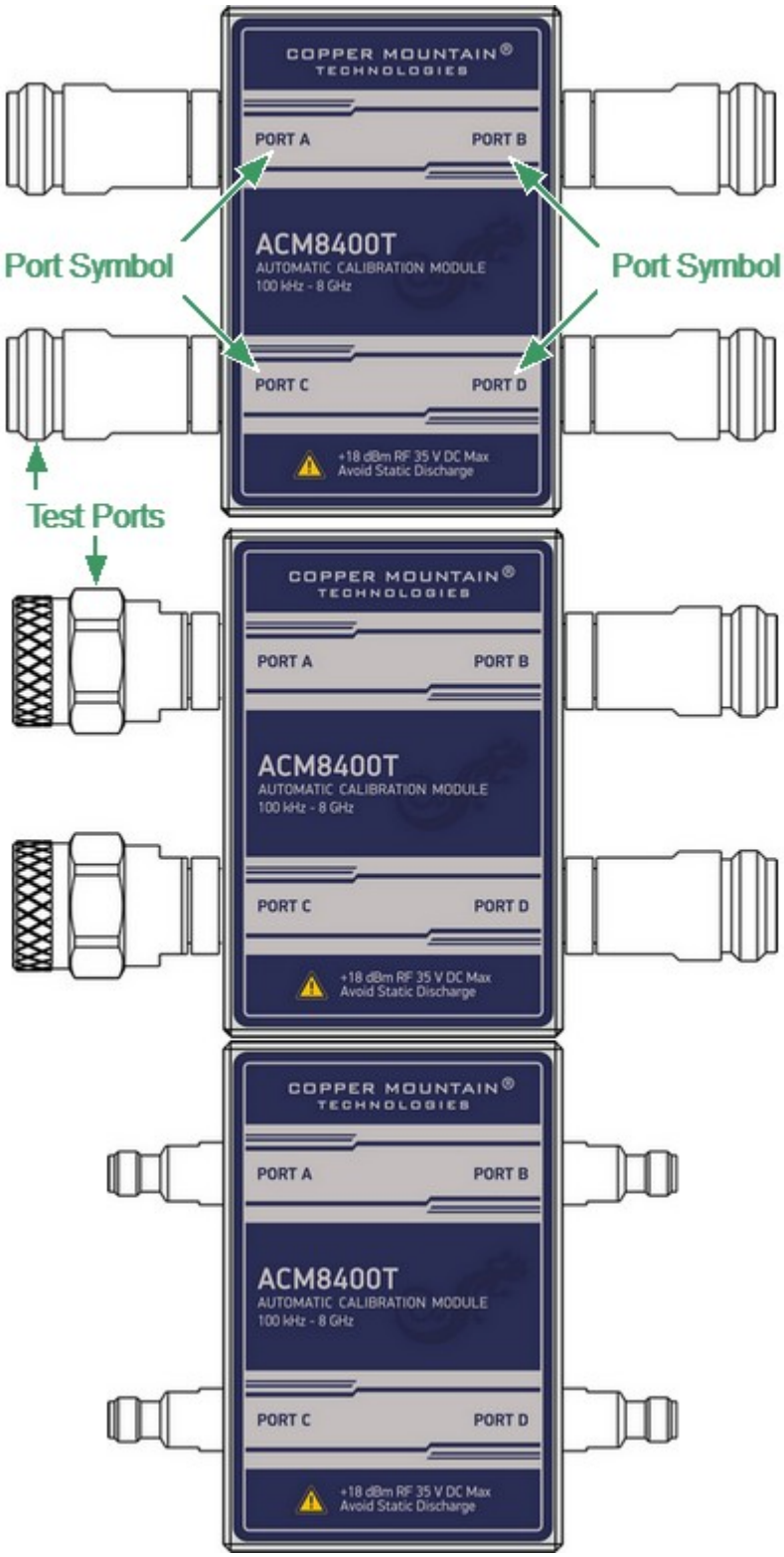
The connector is located on the bottom of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

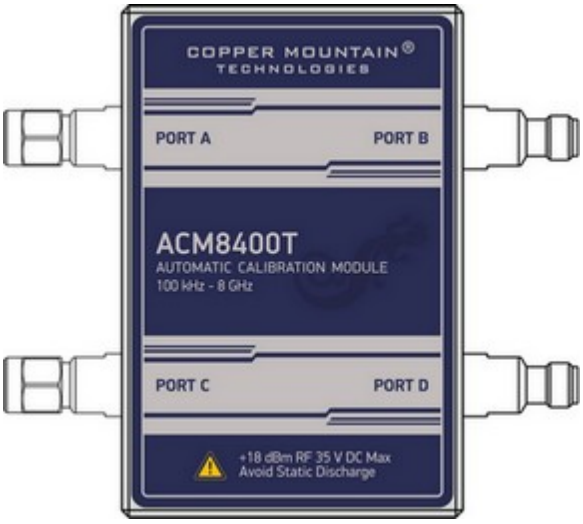
Hardware configurations

Model	Connector type	
	Port A	Port B
ACM8000T-011	type N, female	type N, female
ACM8000T-012	type N, male	type N, female
ACM8000T-111	3.5 mm, female	3.5 mm, female
ACM8000T-112	3.5 mm, male	3.5 mm, female

ACM8400T

The front panels of the different models of ACM8400T are shown in the figure below.





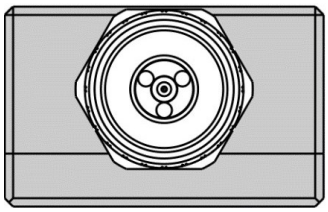
Front panel ACM8400T

Parts of Module

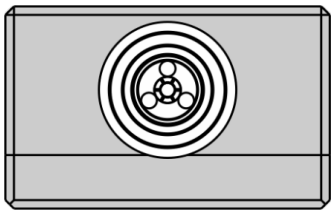
Test port

The test ports are designed for connection to VNA being calibrated. The VNA connectors, the cross sections of which were calibrated, are referred to as its test ports.

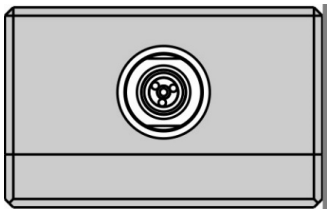
The Modules connectors are shown in figures below.



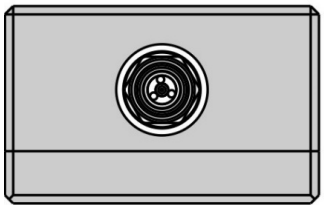
Type N, male



Type N, female

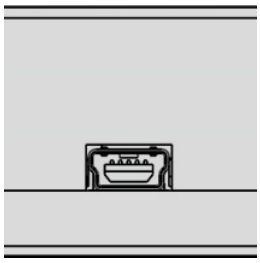


3.5 mm, female



3.5 mm, male

Connector (on side panel)



The connector is located on the bottom of the Module and is intended for the Module connection to the controlling PC. The Module is powered using the USB cable.

LED Status Indicator (on rear panel)

NOTE LED Status Indicator is located under the label and is visible only during operation.

The LED indicates the following statuses:

- Blinking green and red LED mean testing LED and indicating external power supply voltage presence.
- Red LED indicator means warm-up mode of the Module. The time required for operating mode setting is automatically counted from the moment of the Module connection using USB. If the Module is disconnected during setting and reconnected again, then the countdown counter starts from the beginning.

  Additional red LED may indicate the Module connection loss with the PC. In this case, check the Module connection with software (the **Autocalibration** softkey should be active), if there is no connection, disconnect the USB cable from the Module and repeat the connection.
- Green LED indicator means the Module is ready for operation.

Hardware configurations

Model	Connector type	
	Port A/C	Port B/D
ACM8400T-01111	type N, female	type N, female
ACM8400T-01212	type N, male	type N, female
ACM8400T-11111	3.5 mm, female	3.5 mm, female
ACM8400T-11212	3.5 mm, male	3.5 mm, female

Protective Housing

The protective housing is designed to protect the test ports and the USB connector of the automatic calibration module (ACM) from mechanical influences.

The protective housing is removable. The collapsible design allows for quick installation.

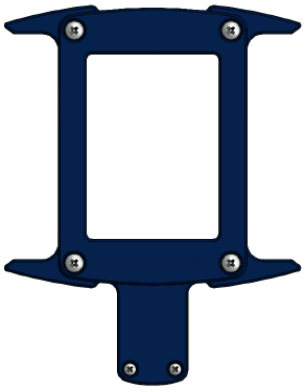
The protective housing is non-repairable.

NOTE The protective housing is not intended for use in extreme environments. Do not bend or stretch the protective housing during use.

The appearance of the protective cover is determined by the modification of the module (See table below).

ACM protective housing

Housing Model	Compatible ACM models
ACM2509 	ACM2506-111, ACM2506-112, ACM2509-111, ACM2509-112, ACM6000T-111,ACM6000T-112, ACM8000T-111, ACM8000T-112
ACM2509 	ACM2506-011, ACM2506-012, ACM2509-011, ACM2509-012, ACM2708-011, ACM2708-111, ACM6000T-011,ACM6000T-012, ACM8000T-011, ACM8000T-012, ACM4000T-511, ACM4000T-512

Housing Model	Compatible ACM models
ACM2520 	ACM2520-011, ACM2520-012, ACM2520-111, ACM2520-112
ACM2543 	ACM2543-611, ACM2543-612, ACM2543-711, ACM2543-712
ACM4509 	ACM4509-01111, ACM4509-01212, ACM4509-11111, ACM4509-11212, ACM84000T-01111, ACM84000T-01212, ACM84000T-11111, ACM84000T-11212

Housing Model	Compatible ACM models
ACM4520 	ACM4520-01111, ACM4520-01212, ACM4520-11111, ACM4520-11212

Delivery Kit

The delivery kit for the Module is represented in table below.

Name	Quantity, pcs
Automatic calibration module	1
USB cable	1
Envelope with ACM certificate of calibration and statement of calibration due date	1
Protective housing	1
1. A specific model of Module is selected in the order. 2. The operating manual is not included in the delivery kit , and can be accessed at www.coppermountaintech.com. 3. The protective housing can be ordered separately.	

NOTE Use the protective housing to protect the test port and USB connector of the Module from mechanical influences (see Protective Housing).

Specifications

The specifications of each Module can be found in its datasheet.

Measurement Capabilities

The VNA software controlling the Module features a wide range of functions. They are briefly described below. See the VNA operating manual for more detailed information.

Automatic Calibration

Calibration	Calibration of a test setup (which includes the VNA, cables, and adapters) significantly increases the accuracy of measurements. Calibration allows for correction of errors caused by imperfections in the measurement system: system directivity, source and load match, tracking, and isolation.
Automatic calibration of VNA	The Module enables calibration in one click. The calibration is performed fully automatically, including switching between different module states, their measurements, and calibration coefficients calculation, as the software uses the data stored in the Module memory.
Calibration methods	All Modules support the following calibration methods: • Full one-port calibration. • One-path two-port calibration. • Full two-port calibration. Four-port Modules support the following additional calibration methods: • Full three-port calibration. • Full four-port calibration.
Full one-port calibration	The method of calibration performed for one-port reflection measurements. It ensures high accuracy.

One-path two-port calibration	The method of calibration performed for reflection and one-way transmission measurements. For example, for measuring S11 and S21 only. It ensures high accuracy for reflection measurements, and reasonable accuracy for transmission measurements.
Full two-port calibration	The method of calibration performed for full S parameter matrix measurement of a two-port DUT. This method is also known as SOLT: Short, Open, Load, Thru. It ensures high accuracy.
Full three-port calibration	The method of calibration performed for full S parameter matrix measurement of a three-port DUT. It ensures high accuracy.
Full four-port calibration	The method of calibration performed for full S parameter matrix measurement of a four-port DUT. It ensures high accuracy.
Unknown thru	The usage of a reciprocal two-port device with loss values of no more than 10 dB for full two-, three- and four-port calibration enables correction of VNA parameters for measuring parameters of non-insertion devices. Non-insertion devices are the devices that have same-gender connectors of any type, and different-gender or same-gender connectors of different types. The Module memory stores S-parameters of the thru which are used for calibration coefficients calculation. The said parameters are not applied for the Unknown Thru algorithm.

Characterization

Characterization	Characterization is a table of S-parameters of all the states of the Module switches, stored in its memory. The Module has two memory sections. The first one is write-protected and contains factory characterization. The second memory section allows to store up to three user characterizations. Before calibration, it is possible to select factory characterization or one of the user characterizations.
Factory characterization	Factory characterization is performed during the Module manufacturing. The factory characterization data is stored in the write-protected section of the Module memory.
User characterization	The user characterization option is provided for saving new S-parameters of the Module after connecting adapters to its ports. Up to three different characterizations can be created. The user characterization can be performed using the VNA software. The characterization data is stored in the Module memory section, which can be overwritten.

Automatic Orientation

Orientation	Orientation refers to the Module ports in relation to the test ports of the VNA. While the VNA ports are indicated by numbers, the Module ports are indicated by the letters A, B, C and D.
Orientation method	Manual or automatic orientation method can be selected.
Automatic orientation	For automatic orientation, the VNA software determines the Module orientation each time prior to its calibration or characterization.

Thermal Compensation

Thermal compensation	Thermal compensation is a software function of S-parameters correction based on known temperature dependence data and the temperature sensor data inside the Module. Temperature dependence of each Module with factory characterization is determined during its manufacture and stored in its memory. It is possible to enable or disable thermal compensation function.
Thermal compensation of user characterization	Thermal compensation of user characterization is based on coefficients obtained during the Module manufacture. If the operating frequency range and/or the number of frequency points of the user and factory characterization are not the same, linear interpolation of thermal compensation coefficients is used for user characterization data.

Confidence Check

Confidence check	The confidence check is a test of the current calibration, performed either by the Module, or by any other method. The confidence check features simultaneous indication of attenuator S-parameters measured and stored in the Module memory. Math (division) function for data and memory is used for a detailed comparison.

Automation

Operating modes	The Module is controlled using the USB interface. CMT's VNA software or VISA library must be installed at the controlling PC. The VISA comprehensive library allows controlling measurement equipment in almost all programming languages, i.e. C/C++, Visual Basic, MATLAB, LabVIEW, etc. The Module features the USBTMC USB488 standard control protocol. The Programming Manual includes descriptions of commands used for controlling.

Principle of Operation

The Module contains several different transmission and reflection impedance states, as well as electronic changeover switches, two or four RF connectors, and a USB connector. RF connectors are intended for connecting to VNA test ports, and a USB connector is intended for controlling.

Module	States
ACM2506, ACM2509, ACM2708, ACM4000T, ACM6000T	6 reflection states (three for each port), a THRU, and an attenuator.
ACM2520	8 reflection states (four for each port), a THRU, and an attenuator.
ACM2543, ACM8000T	10 reflection states (five for each port), a THRU, and an attenuator.
ACM4509, ACM8400T	16 reflection states (four for each port), a THRU, and an attenuator.
ACM4520	12 reflection states (three for each port), a THRU, and an attenuator.

Calibration is performed by automatically connecting internal transmission and reflection impedance states to the VNA test ports.

Calibration allows determining systematic errors according to the VNA model. The data obtained after calibration is used to correct S-parameter measurement results to increase measurement accuracy.

Block diagrams of Modules are represented in Module Block Diagrams.

Types of Calibration Standards

Calibration standards are physical devices with known parameters used for VNA calibration, with the purpose of calculating systematic errors and further correcting the measurement results.

OPEN, SHORT, and LOAD are the reflection standards, and THRU is the transmission standard (transmission connection).

The Module includes four types of calibration standards:

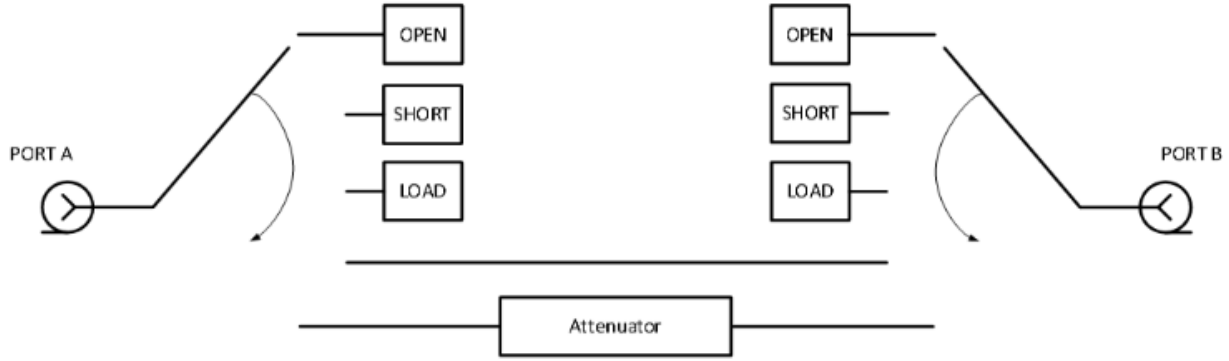
- OPEN
- SHORT
- LOAD
- THRU

Attenuator

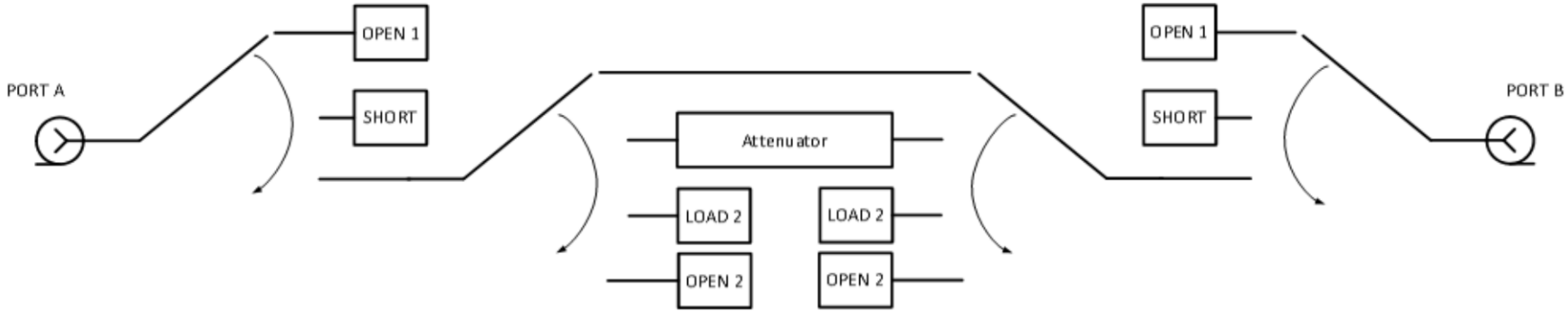
The Module features additional attenuator state, which is not used during calibration. The attenuator is used for checking calibration quality using a special confidence check function, which allows for comparing of the measured S-parameters of attenuator with the parameters stored in the Module memory.

Module Block Diagrams

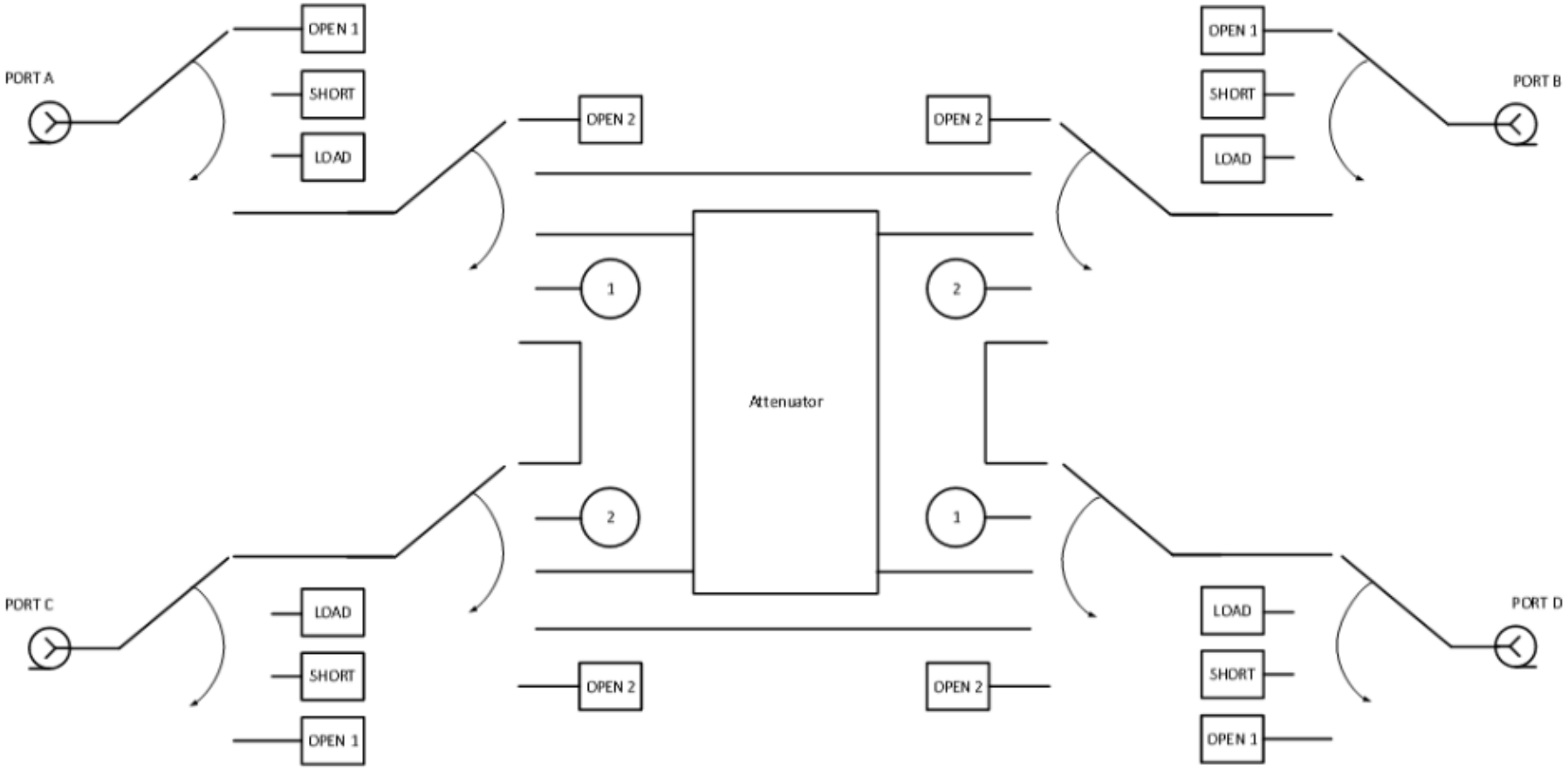
Module block diagrams are shown in figures below.



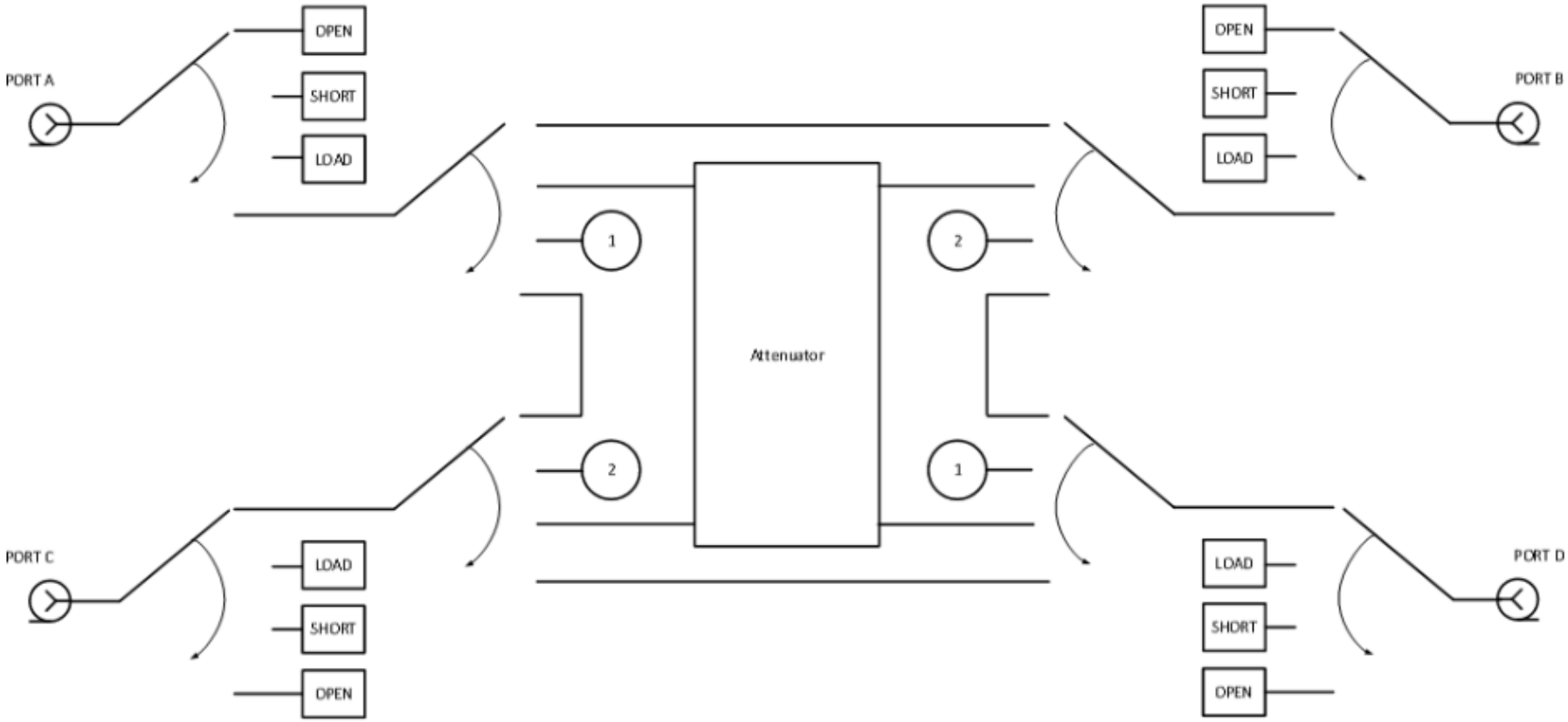
Block diagram of ACM2506 and ACM2509



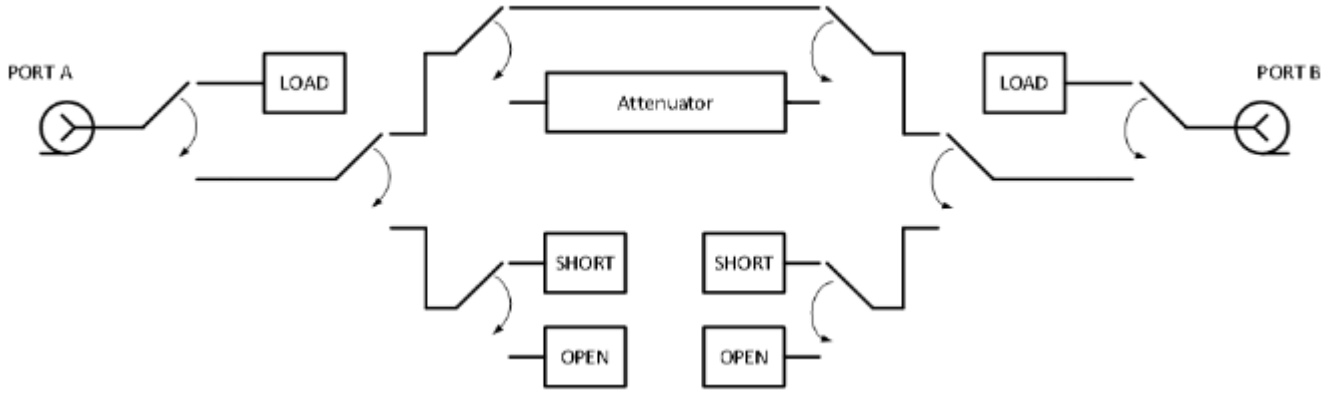
Block diagram of ACM2520



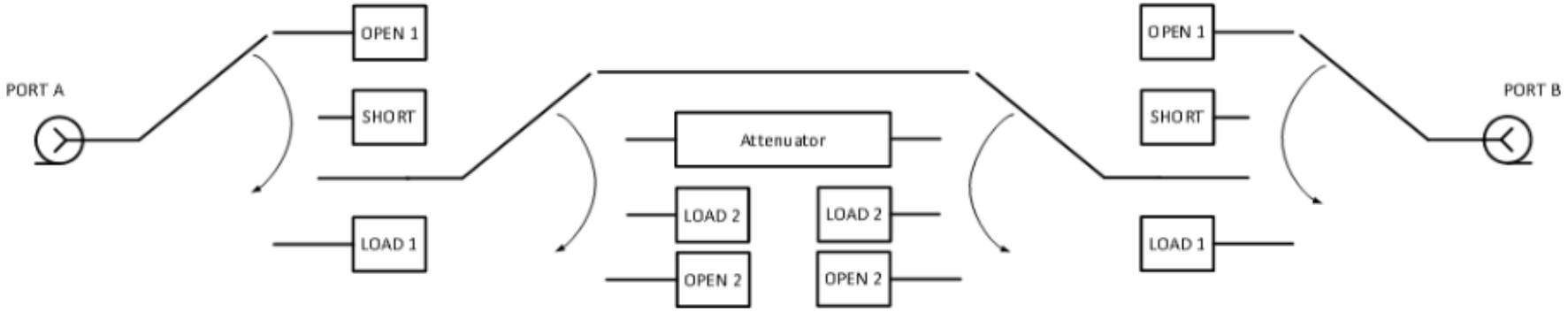
Block diagram of ACM4509 and ACM8400T



Block diagram of ACM4520



Block diagram of ACM2708, ACM4000T and ACM6000T



Block diagram of ACM8000T and ACM2543

Preparation for Use

Unpack the Module and other accessories.

CAUTION	Please keep packaging to safely ship the instrument for annual calibration!

The following section describes the process of preparing the ACM for use:

- Operating Restrictions.
- Installation.
- Software.

Operating Restrictions

The accuracy of calibration using the Module largely depends on proper handling of the Module while preparing it for use. Keep all connectors clean and undamaged to increase the Module's service life. Dirty or damaged connector can deteriorate accuracy characteristics and materially affect the VNA calibration results.

Before starting operation, perform the following activities to prevent the Module damage:

- Visually inspect the connectors, the Module housing, and the USB cable from the delivery kit for damages and contamination. If foreign particles are detected on the connectors, perform cleaning according to the procedure in Cleaning Connectors. Do not operate the Module if mechanical connector damage is detected. Damaged Modules should be discarded to prevent further damage of other good connectors.
- Visually inspect the connectors, which will be connected to the Module, for damages and contamination. If foreign particles are detected on the connectors, perform cleaning according to the procedure in Cleaning Connectors.
- If necessary, gauge the connectors using the procedure described in Gauging Connectors, which describes connection of the Module and devices connected to it.

Pay special attention to the connection sequence. Proper connection sequence prevents central and external conductors damage, ensures maximum measurement results repeatability, and excludes the most common VNA measurement error, i.e. bad connection. The recommended connection sequence is shown in Connecting and Disconnecting Devices.

The main cause of measurement accuracy deterioration is the change of ambient conditions between the calibration and DUT measurement. The ambient conditions are described in Ambient Conditions Control.

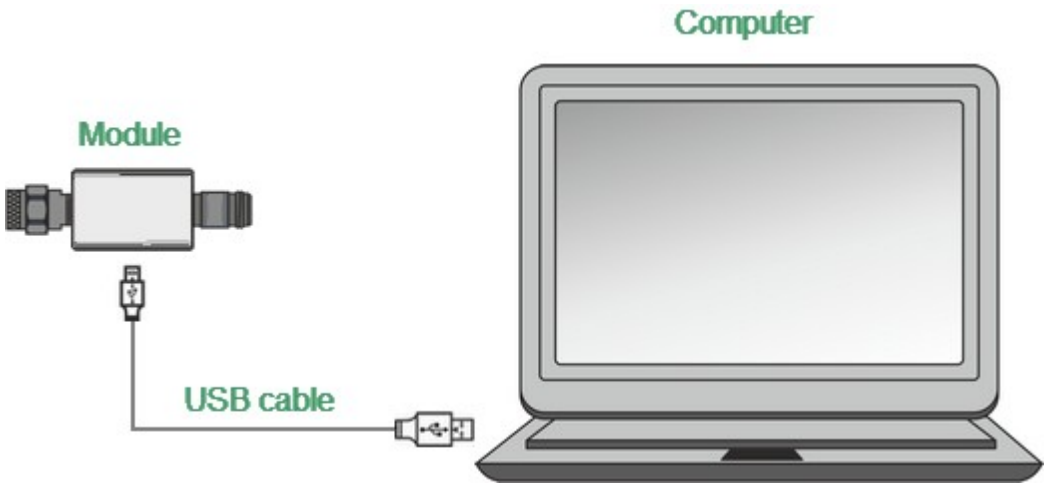
Installation

Unpack the Module and place the Module in the work area.

Take necessary precautions to protect against electrostatic discharge in the work area.

Keep the Module in operating conditions for no less than two hours if it was stored in any other ambient conditions.

Connect the Module using the USB cable. Warm the Module up for no less than 15 minutes. The warm-up connection procedure is shown in the figure below.



Module connection to PC

Typical Module connection diagrams for VNA calibration are shown in Connection Diagrams.

Software

The Module is controlled by the Copper Mountain Technologies VNA software. Minimum technical requirements to the PC and the description of software installation are described in the VNA Operating Manual.

The VNA software automatically detects the connected Module and makes the Autocalibration menu available. Special Module selection is not generally required.

If the menu is not active:

1. Shut down all the open VNA software windows.
2. Disconnect the Module from the USB cable for one minute, then reinsert the cable.
3. Restart the VNA software, making sure that the VNA software functions properly according to the VNA Operating Manual.
4. Connect the Module again, making sure that the model and serial number match the Module connected.

Driver installation

The USB driver is automatically installed when the Module is first connected to the USB port.

Operation Procedure

This section describes how to work with the Module:

- Connection diagrams to perform calibration.
- Module work session.
- Parameters setting.

Connection Diagrams

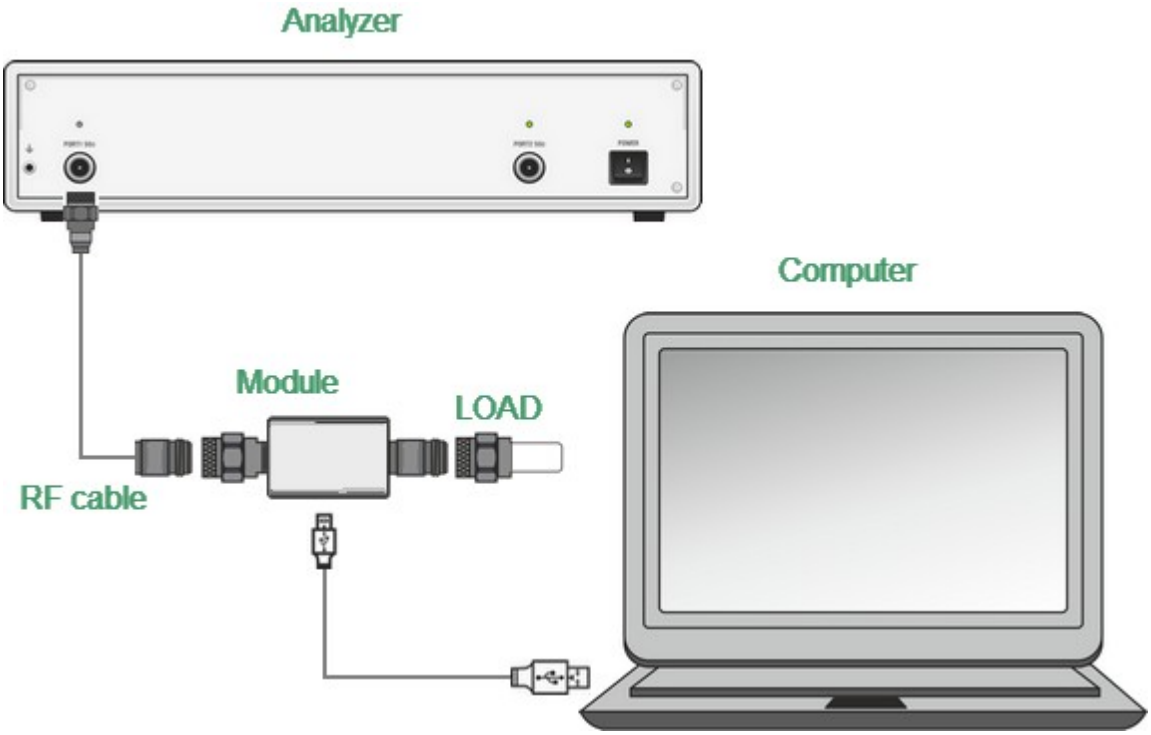
The following are connection diagrams for calibrations:

- Full One-Port Calibration
- One-Path Two-Port and Full Two-Port Calibration
- Full Three-Port Calibration
- Full Four-Port Calibration

Full One-Port Calibration

In order to perform calibration, it is recommended to connect a LOAD to a free port of the Module. The LOAD is not included in the delivery kit.

Typical connection diagram for full one-port calibration is shown in figure below.



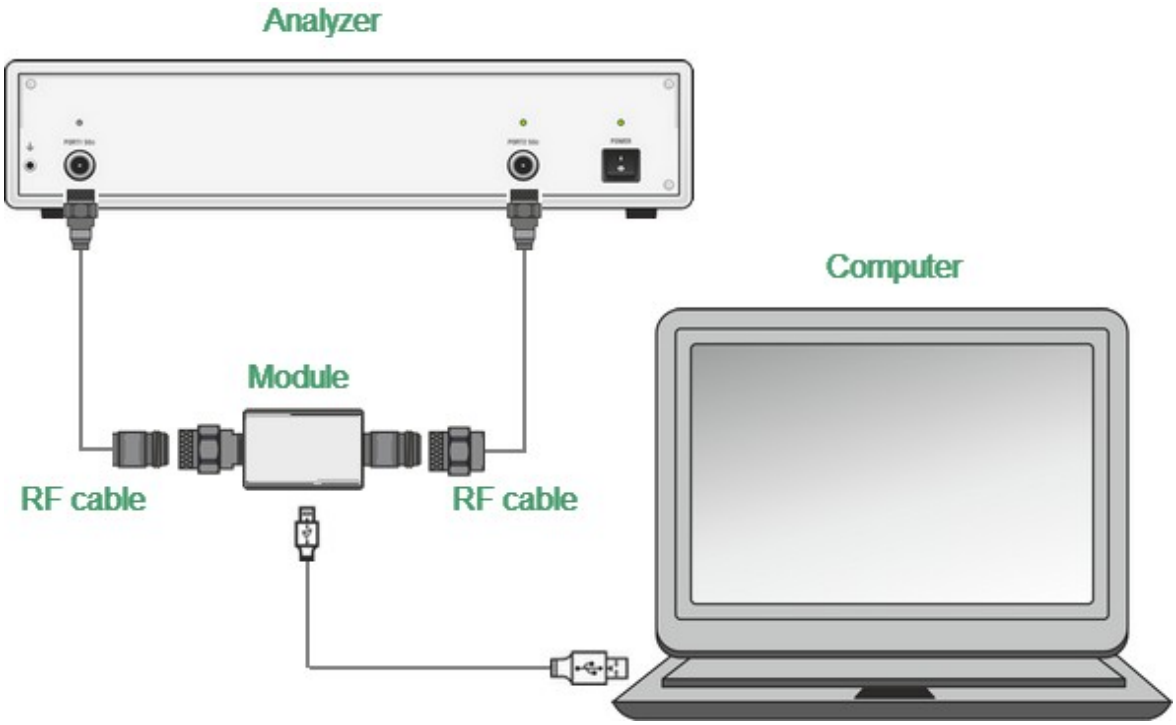
Module connection diagram for performing full one-port calibration

To prevent the cable from damage and improve the stability, it is recommended to use additional protection metrology-grade adapters (these adapters are not shown in figure).

WARNING Use a torque wrench to tighten the male connector nut. Use a spanner to prevent the connected devices from rotation.

One-Path Two-Port and Full Two-Port Calibration

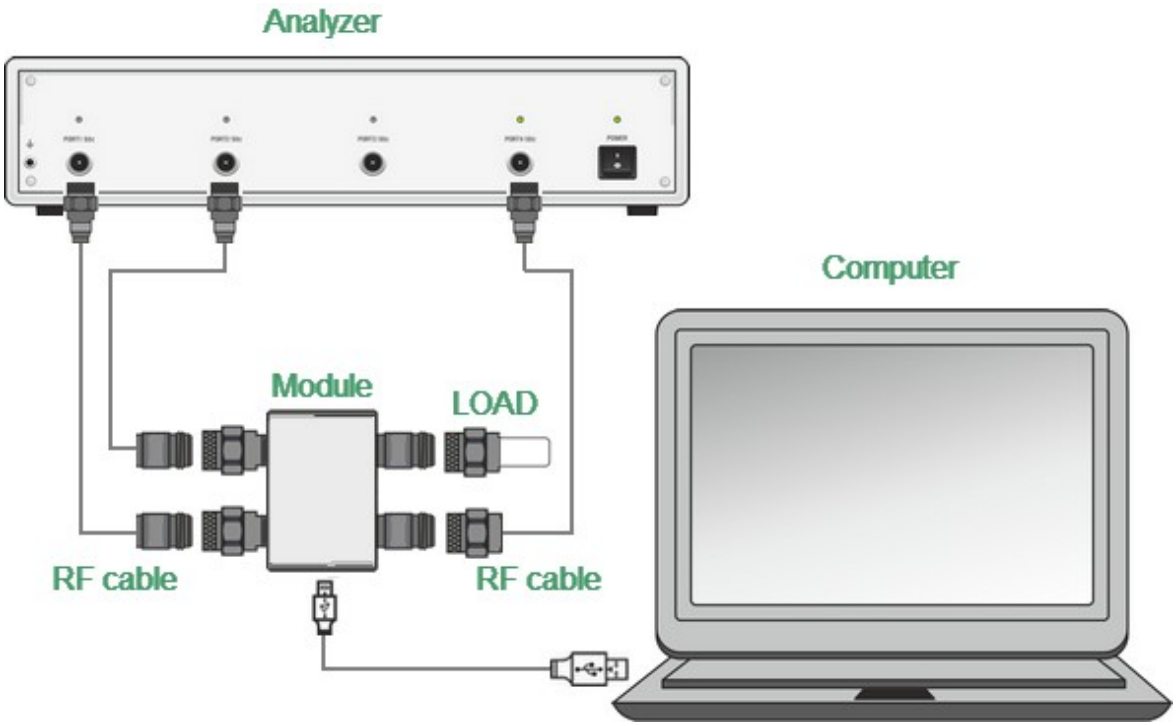
Typical connection diagram for one-path two-port and full two-port calibration is shown in figure below.



Module connection diagram for performing one-path two-port and full two-port calibration

Full Three-Port Calibration

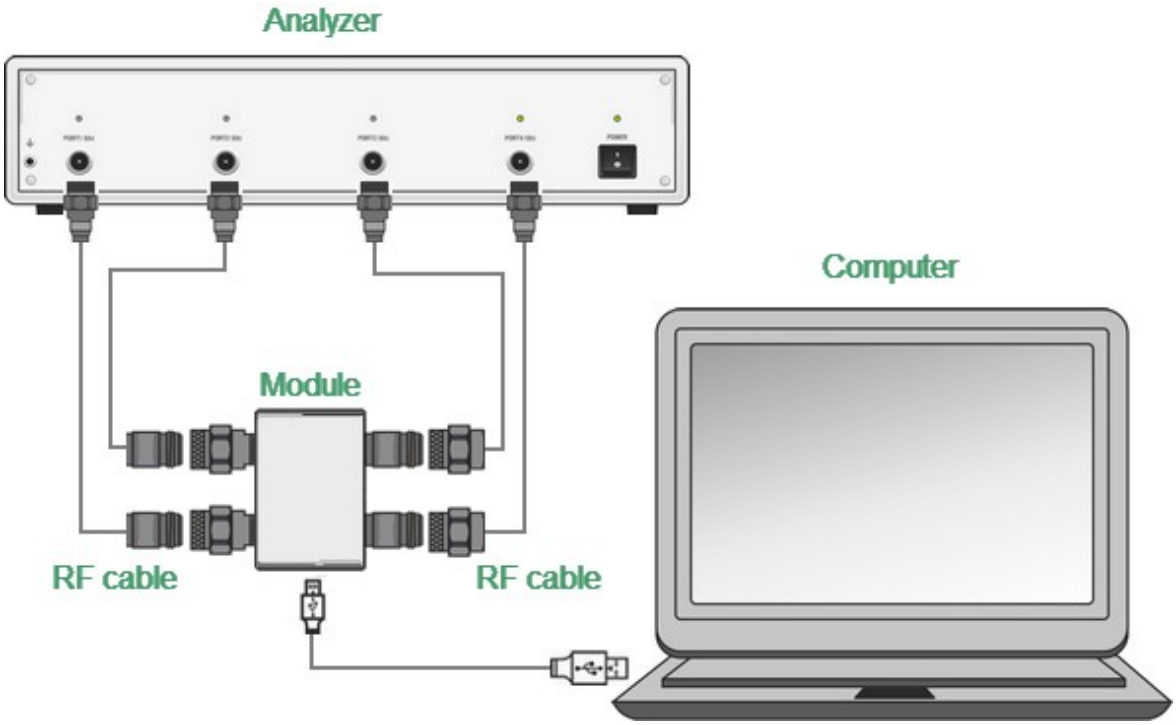
In order to perform calibration, connect a LOAD to a free port of the Module. A typical connection diagram for performing full three-port calibration is shown in the figure below.



Module connection diagram for performing full three-port calibration using ports 1, 2 and 4

Full Four-Port Calibration

A typical connection diagram for performing full four-port calibration is shown in the figure below.



Module connection diagram for performing full four-port calibration

Module Work Session

This section includes the example of the Module work session. Perform the following activities to calibrate all types of VNAs:

- Locate the Module at the work site and warm it up for at least 15 minutes.
- Set up the VNA parameters, at which calibration and DUT parameters measurement will be performed.
- Assemble a test setup.
- Connect the Module (typical connection diagrams are shown in Connection Diagrams).
- Perform the required calibration.
- Disconnect the Module and connect the DUT in its place.

Module Preparation for Calibration

Locate the Module on the work bench, switch it on, and warm it up for at least the period of time indicated in the datasheet. If the model used is equipped with an LED status indicator, wait until the LED is green.

WARNING	The technical specifications will correspond to the stated specifications only after the operating mode setup time is over.

Module readiness indication	The VNA software can automatically detect the connected Module. After the Module connection, the VNA software makes the Autocalibration menu available.

Parameters Setting

Before starting measurements and calibration, set up the following VNA parameters:

- Set up default parameters.
- Select the traces and assign measured S-parameters to them.
- Set up the frequency range and the number of frequency points.
- Set up the output power level at no more than -5 dBm.
- Set up the IF bandwidth.

These parameters are set up in the VNA software. The setting procedure is described in detail in the VNA Operating Manual.

Calibration

The following section describes the process of calibrating ACMs.

Module Advantages

Calibration involving the Module has several advantages compared to conventional calibration with a kit of mechanical calibration standards:

- Only one connection required.
- Reduced calibration time.
- Less probability of operator's mistakes.
- Less wear of VNA test ports connectors.

Measurement Errors

Different measurement errors affect the results of VNA S-parameter measurements. The measurement errors can be divided into two categories:

- Systematic errors.
- Random errors.

Random errors are:

- Noise fluctuations and thermal drift in electronic components.
- Changes in the mechanical dimensions of cables and connectors subject to temperature drift.
- Repeatability of connections and cable bends.

Random errors are unpredictable and hence cannot be estimated and eliminated in calibration. Certain measures can be taken to reduce the random error:

- Proper source power selection.
- Narrower IF bandwidth.
- Constant ambient temperature.
- Proper warm-up time.
- Careful handling of connectors.
- Fewer cable bends after calibration.
- Sage of torque wrench to tighten the male connector nut and spanner to prevent the connected devices from rotation.

Systematic errors occur when the test setup components are not in ideal conditions. They are repeatable, and their characteristics do not change in time. Systematic errors can be calculated, and their value can be reduced mathematically by measurement results correction.

Calibration Types

The Modules enable three types of calibration:

- Full one-port calibration
- One-path two-port calibration
- Full two-port calibration

Four-port Modules additionally enable two types of calibration:

- Full three-port calibration
- Full four-port calibration

The calibration procedure is described in Calibration Procedure.

Full One-Port Calibration

The three calibration standards are measured in the process of this calibration:

- SHORT
- OPEN
- LOAD

Full one-port calibration features high accuracy.

One-Path Two-Port Calibration

One-path two-port calibration combines full one-port calibration and extended transmission normalization. This calibration type features higher accuracy of measuring frequency response flatness compared to transmission normalization.

One-path two-port calibration requires connection of three calibration standards to the source port, just as in one-port calibration, as well as a connection of the THRU calibration standard between the calibrated source port and the receiver port.

Full Two-Port Calibration

Full two-port calibration requires connection of seven calibration standards:

- Two OPEN calibration standards.
- Two SHORT calibration standards.
- Two LOAD calibration standards.
- One two-port THRU calibration standard.

This calibration type combines two one-port calibrations for each test port with the measurement of transmission and reflection of a THRU standard in both directions.

Full two-port calibration features high accuracy.

Full Three-Port Calibration

Full three-port calibration requires the connection of 12 calibration standards. It combines full one-port calibrations for each test port with measurement of transmission and reflection of a THRU standard in both directions for each couple of ports.

Full three-port calibration features high accuracy for three-port measurements.

Full Four-Port Calibration

Full four-port calibration requires the connection of 18 calibration standards. It combines full one-port calibrations for each test port with measurement of transmission and reflection of a THRU standard in both directions for each couple of ports.

Full three-port calibration features high accuracy for four-port measurements.

Unknown Thru

UNKNOWN THRU is used in full two-, three-, and four-port calibration. The calibration type with an UNKNOWN THRU is called SOLR, which refers to Short, Open, Load, Reciprocal.

Any arbitrary reciprocal two-port device with unknown parameters can be used as an UNKNOWN THRU.

There are two basic requirements to the UNKNOWN THRU:

- The first requirement applies to the transmission coefficient of the THRU. It should satisfy the reciprocity condition (S21 = S12), which holds for almost any passive network. Do not use a THRU with a loss higher than 20 dB, as it can reduce the calibration accuracy.
- The second requirement is knowledge of the approximate electrical length of the UNKNOWN THRU within an accuracy of 1/4 of the wavelength at the maximum calibration frequency. This requirement, however, can be omitted if the following frequency step size condition is met:

$$\Delta F < \frac{1}{4 \cdot \tau_0},$$

where τ_0 is a delay of reciprocal two-port device.

In this case, the VNA software can automatically determine electrical length (delay) of a reciprocal two-port device.

A thru, implemented inside the Module using an electronic switch, features loss. Make sure the exact thru parameters are known, or use an UNKNOWN THRU algorithm to obtain the required calibration accuracy.

The Module allows the use of both variants. Its memory stores S-parameters of the thru, which are used for calculation of calibration coefficients. The above parameters are not used if the UNKNOWN THRU algorithm is applied.

Thermal Compensation

Thermal compensation is a software function of the Module parameters correction using the data of internal temperature sensor and data on temperature dependence.

The Module temperature dependence data are the thermal compensation coefficients of magnitude and phase of reflection or transmission coefficients for different Module states stored in its memory.

The compensated magnitude value M_c, dB, is calculated using the following formula:

$$M_c = M \cdot k_m \cdot (T_{char} - T)$$

where M — magnitude before compensation, dB,

k_m — thermal compensation coefficient magnitude, dB/ºC,

T_{char} — temperature at Module characterization, ºC,

T — current temperature inside the Module housing, ºC.

Compensated phase value, P_cº , is calculated using the following formula:

$$P_c = P \cdot k_p \cdot (T_{char} - T) \ ,$$

where P — phase value before compensation, º

k_p — thermal compensation coefficient phase, º/ºC,

T_{char} — temperature at Module characterization, ºC,

T — current temperature inside the Module housing, ºC,

Temperature dependence of S-parameters of each Module is measured at the factory and stored in its memory.

Thermal compensation can be applied to the factory or user characterization data.

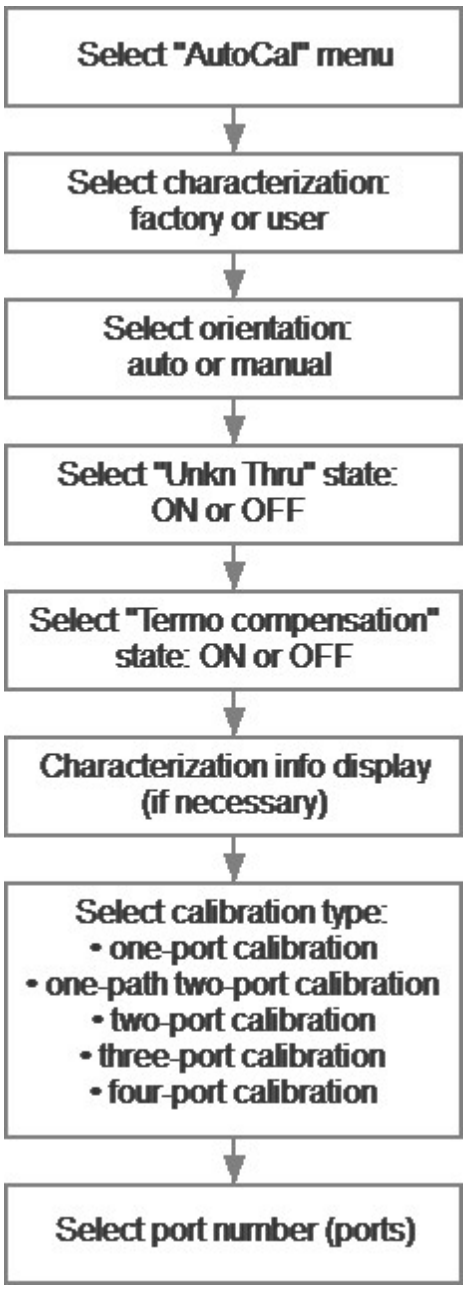
The thermal compensation function can be enabled or disabled.

Calibration Procedure

Calibration is performed in fully automatic mode. The calibration procedure is the following:

1. Press the calibration softkey in the software main menu.
2. Select automatic calibration in the resulting menu. The autocalibration softkey becomes active after the Module connection (typical connection diagrams are shown in Connection Diagrams).
3. Press the characterization softkey.
4. Select factory characterization or one of three user characterizations (user characterization procedure is described in User Characterization Procedure) in the characterization menu.
5. Select the Module orientation method by pressing the orientation softkey.
6. Select the unknown thru algorithm state. The unknown thru algorithm can be either enabled or disabled.
7. Select the thermal compensation function state. The thermal compensation function can be either enabled or disabled.
8. If necessary, display the detailed information on characterization. The information can be displayed by pressing the respective softkey in the autocalibration menu.
9. Select the calibration type: one-port, two-port, three-port, or four-port.
10. Specify the port for full one-port calibration, two ports for full two-port calibration and three ports for full three-port calibration.
11. Wait until calibration is completed.

The automatic calibration algorithm is shown in the figure below.



Autocalibration algorithm

The calibration will be performed automatically: the standards from the Module set will be connected to VNA in sequence under the VNA software control. Then the calibration coefficients table will be calculated and stored in the VNA memory.

When calibration is completed, certain icons will be indicated in the status bars of reflection and transmission coefficients traces:

- **[F1]** — full one-port calibration.
- **[OP]** — one-path two-port calibration.

- **[F2]** — full two-port calibration.
- **[F3]** — full three-port calibration.
- **[F4]** — full four-port calibration.

Detailed information on calibration using the Module and the names of all softkeys for all VNAs can be found in the VNA Operating and Programming Manual.

User Characterization Procedure

Characterization is the process of calculation of S-parameters table for all Module states.

User characterization of the Module is required if the Module connectors were modified using the adapters. The new device, including the Module and adapters, is characterized.

Before performing the user characterization of the two-port Module, ensure that the two-port VNA calibration has been performed with the port setup matching the Module.

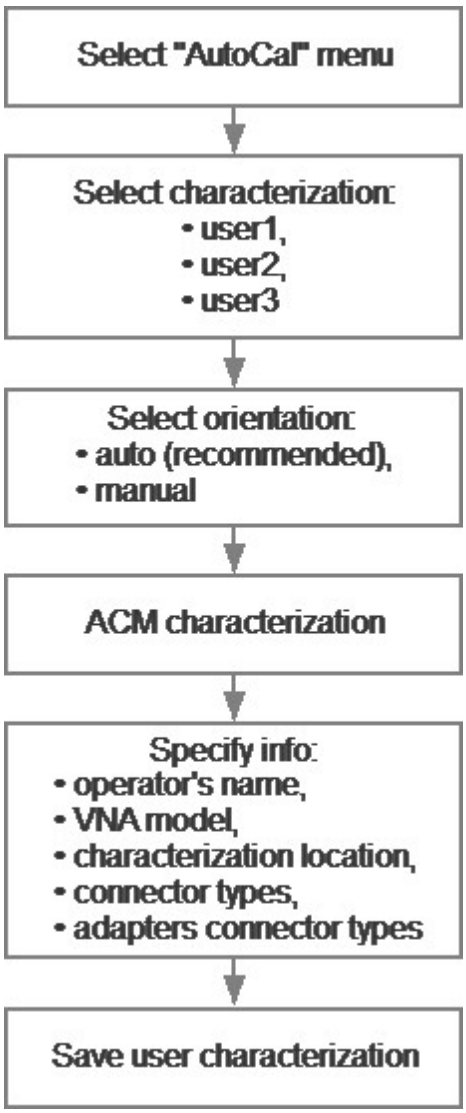
Before performing the user characterization of the four-port Module, ensure that the four-port VNA calibration has been performed with the port setup matching the Module.

The Module is characterized together with its adapters. To save the characterization, do not disconnect and reconnect the adapters which were characterized with the Module. If the adapters are disconnected, the user characterization should be performed again.

User characterization procedure in the VNA software:

1. Press the calibration softkey in the software main menu.
2. Select automatic calibration in the resulting menu.
3. Press the characterization selection softkey in the autocalibration menu.
4. Select one of three user characterizations in the characterization menu.
5. Select the Module orientation method by pressing the orientation softkey in the autocalibration menu. It is recommended to use automatic orientation.
6. Start the Module characterization by pressing the respective softkey in the autocalibration menu.
7. Specify the following information in the pop-up dialog box:
    - Operator's name.
    - VNA model.
    - Characterization location.
    - Connector types.
    - Adapters connector types.
8. Press the save softkey to complete the Module user characterization.

The user characterization procedure is shown in the figure below.



User characterization algorithm

Detailed information on the Module user characterization and the names of all softkeys for all VNAs can be found in the VNA Operating and Programming Manual.

Confidence Check

Confidence check is a test of current calibration performed either using the Module or any other method.

The Module features an additional attenuator state that is not used during calibration. The attenuator is intended for checking calibration by means of a special software function, which enables comparison of measured attenuator S-parameters and the values stored in the Module memory.

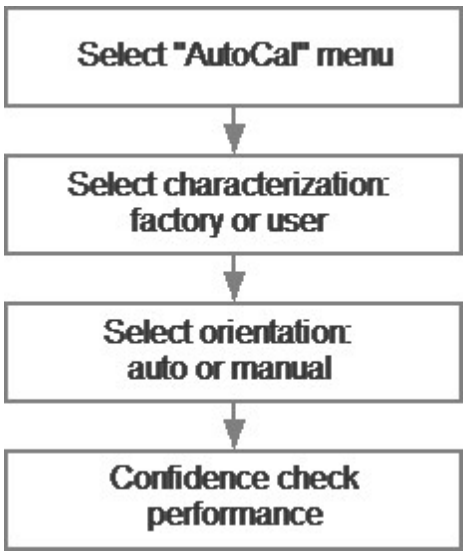
Confidence check procedure

1. Press the calibration softkey in the software main menu.
2. Select automatic calibration in the resulting menu.
3. Press the characterization selection softkey in the autocalibration menu.
4. Select factory characterization or one of three user characterizations in the characterization menu.
5. Select the Module orientation method by pressing the orientation softkey in the autocalibration menu. It is recommended to use automatic orientation.
6. Press the «Confidence Check» softkey in the autocalibration menu.
7. Wait until the confidence check is completed.

The confidence check will be performed automatically. Two traces for each S-parameter will be displayed after measurement. The measured parameters will be indicated on the data trace, and the parameters from the Module memory will be indicated on the memory trace.

Compare the data and memory traces to evaluate whether the calibration was successful. Also, the function of math operations with memory traces for a finer trace comparison can be used.

Confidence check algorithm is shown in the figure below.



Algorithm of confidence check using the Module

Detailed information on the Module confidence check and the names of all softkeys for all VNAs can be found in the VNA Operating and Programming Manual.

Automation

The Module supports remote control using third party software. The control function is implemented by means of USB protocol. The VISA library must be installed on the PC for interaction.

The library allows for controlling of measuring equipment in almost any programming language, i.e. C/C++, Visual Basic, MATLAB, LabVIEW, etc. The VISA laboratory supports multiple interfaces and protocols, including USBTMC-USB488 based protocol implemented in the Module.

For detailed information on control functions, see the VNA Operating and Programming Manual.

Maintenance

This section establishes the procedure and rules of maintenance, enabling constant Module operational readiness.

The purpose of Module maintenance is to control its performance parameters and secure its service life.

Maintenance Procedure

The Maintenance Procedure is as follows:

- Maintenance Activities
- Cleaning Connectors
- Gauging Connectors
- Connecting and Disconnecting Devices
- Cleaning and Care of the Protective Housing
- Ambient Conditions Control
- Verification

Maintenance Activities

The Module maintenance includes the following activities:

- Inspection.
- Functional test.

The inspection should be done every time before and after the Module is used.

The inspection comprises:

- Checking components against the delivery kit list.
- Cleaning dust and dirt from external surfaces of the Module. To clean the Module's external surfaces, use dry or slightly wet cloth. Do not clean the Module inside.
- Cleaning connectors as described in Cleaning Connectors.

Functional test should be carries out once per 100 connections.

The functional test includes:

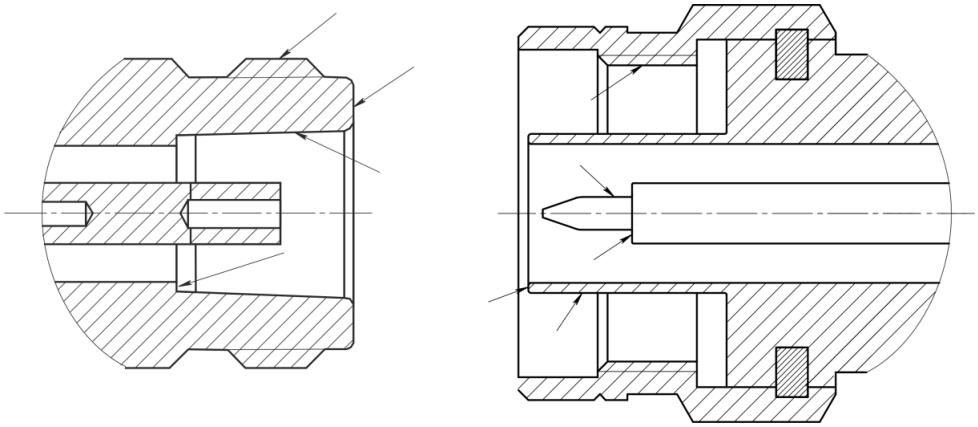
- Inspection.
- Module connectors gauging as described in Gauging Connectors.
- Confidence check.

Cleaning Connectors

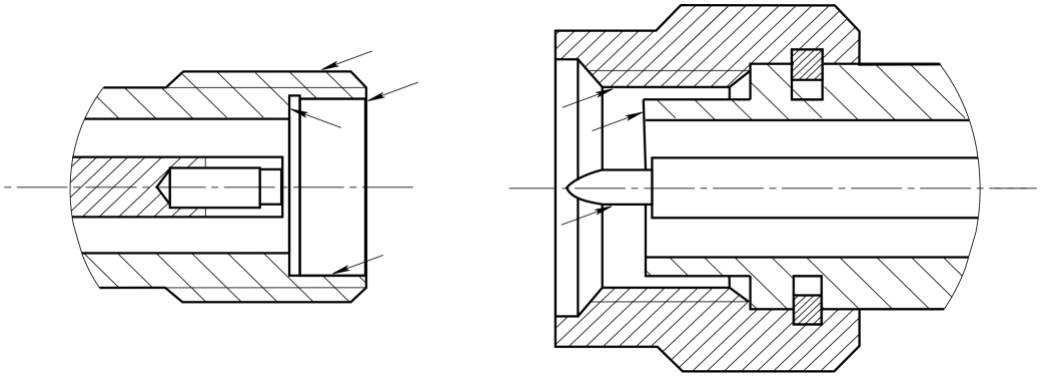
Clean the connectors before and after connecting the Module.

The procedure of cleaning connectors:

1. Wipe the connector surfaces as shown by the arrows in the figures below with a swab dipped in alcohol.



Type N connectors



2.4 mm, 2.92 mm, 3.5 mm connectors

2. Use compressed air to clean another internal connector surface.
3. Let the alcohol dry on the connector surfaces.
4. Visually inspect the connectors to make sure that no particles or residue remain.
5. Repeat the cleaning procedure if necessary.

WARNING

NEVER use metal items for cleaning connectors.

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

Gauging Connectors

Gauge the connectors before using the Module for the first time, and regularly during operation.

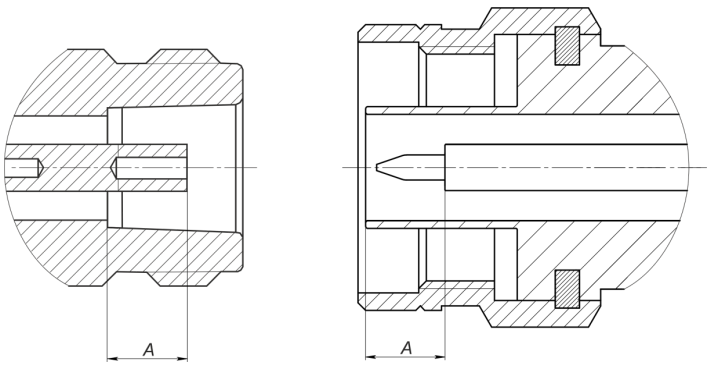
The first gauging of connectors obtains pin depth, which can be used during the Module operation to evaluate its changing.

Gauge the connectors again if:

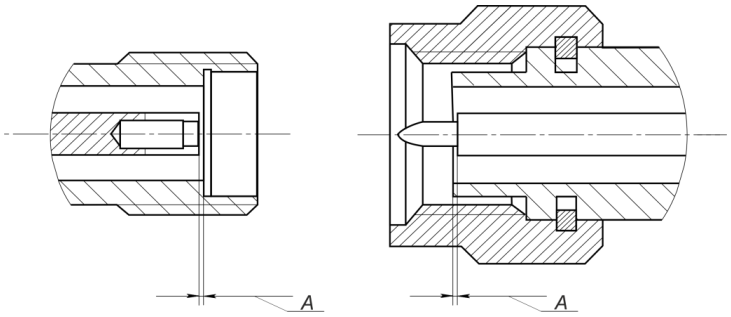
- A visual inspection or Module calibration results suggest that the connector may have defects or damages.
- The device connectors used with the Module are damaged or their pin depth values are out of range for this type of connectors.
- After every 100 connections.

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.

The pin depth of the connectors “PORT A”, “PORT B” and, if available, “PORT C” and “PORT D” are subject to verification. Only measure the A pin depth of type N connectors and 3.5 mm connectors (See figures below).



Type N connectors (female and male)



2.4 mm, 2.92 mm, 3.5 mm connectors (female and male)

The A pin depth value of Module ports connectors must be within the following ranges:

Connectors type	Pin depth range
Type N, female	5.18 to 5.26 mm
Type N, male	5.28 to 5.36 mm
2.4 mm, 2.92 mm, 3.5 mm, male	- 0.08 to 0.00 mm
2.4 mm, 2.92 mm, 3.5 mm, female	- 0.08 to 0.00 mm

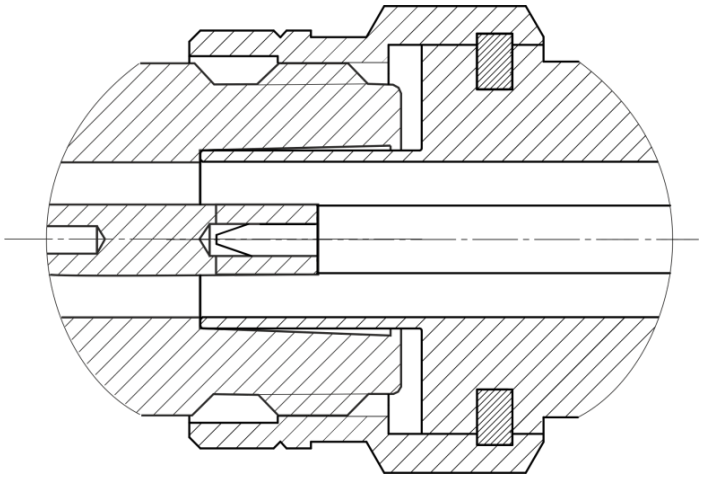
The A pin depth value ranges for connectors of other devices are be indicated in their operating manuals.

WARNING If the pin depth values of the gauged connectors are out of the specified range, such connectors are subject to repair (See Routine Repairs). A device with such connectors is discarded.

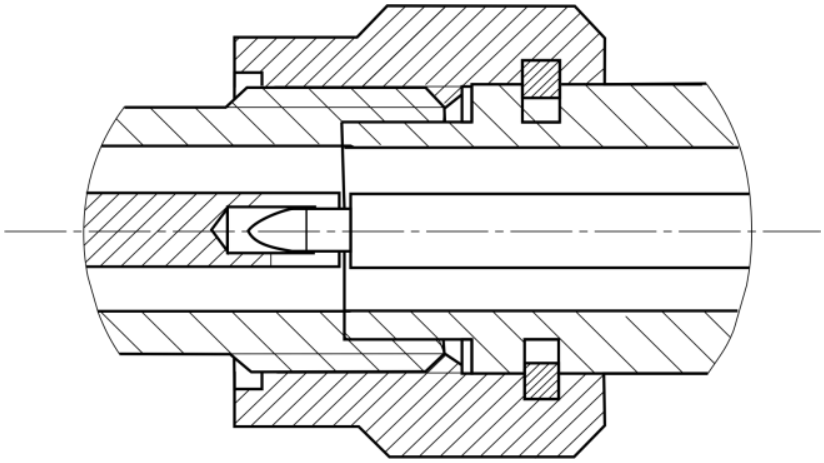
Connecting and Disconnecting Devices

The Module connectors should be connected in the following order:

1. Fix the housing of one of the devices being connected. This is necessary to avoid its displacement during connection. Fix the device by any of the following ways:
    - By clamps or wrenches.
    - By weight or configuration of the device itself.
    - By holding the device by hand
2. Carefully align the connectors of the connected devices.
3. While holding the device being connected, tighten the male connector nut finger tight. Mating plane surfaces of center conductors and outer conductors have to make uniform light contact as shown in the figures below.
4. Tighten the male connector nut using the appropriate torque wrench (the torque value depends on the connector type), while holding the device being connected manually or by using 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 just to the torque wrench break point.



Type N connectors (female on the left, male on the right)



2.4 mm, 2.92 mm, 3.5 mm connectors (female on the left, male on the right)

Disconnect the connectors in the following order:

1. 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.

2. While holding the device so that the connector's center conductor was at the same straight line as it was connected, turn the male connector nut. Pull the connectors straight apart.

WARNING Do not use alcohol, alkali, or acid for cleaning.

Cleaning and Care of the Protective Housing

The protective housing is not intended for use in extreme environments. Do not bend or stretch the protective housing during use.

Clean the protective housing with a lint-free cloth, slightly dampened with water. Clean the protective housing when it is disassembled.

WARNING Do not use alcohol, alkali, or acid for cleaning.

Ambient Conditions Control

The measurement accuracy can be severely affected by the change of environmental conditions (especially ambient temperature) between the VNA calibration and the DUT measurements.

The measurements should be performed at an ambient temperature within ±1 °C of the temperature at the time VNA calibration.

Verification

Copper Mountain Technologies recommends following the industry's best practices and user quality policies to determine the ACM verification period. Consider frequency of use, environmental conditions, and storage procedures. The suggested verification interval is 1-3 years.

Routine Repairs

Only authorized routine repair or repair by the licensed company is permitted. The repair method is non-differential.

Routine repairs	Repairs performed to enable or restore the device performance, which includes replacement and/or recovery of separate parts.
Non-differential method	The method of repairs at which the restored constituent parts do not belong to the specific device instance.

Storage Instructions

Module can be stored in the factory packaging at 0 to +40 ºC and a relative humidity of up to 80% (at 25 ºC). After the factory packaging is removed, the Module should be stored at +10 to +35 ºC and relative humidity up to 80% (at 25 ºC).

Keep the storage facilities free from dust, fumes of acids and alkalis, aggressive gases, and other chemicals, which can cause corrosion.

Transportation

Load and unload the Module packages carefully, avoiding shock and packaging damage. Use the markings on the package to place the Modules correctly during transportation.

The Modules must be shipped in any closed vehicle at temperature from -50 to +70 ºC, a relative humidity of 95% (at 30 ºC), and an atmospheric pressure of 70 to 106.7 kPa (537 to 800 mm Hg).

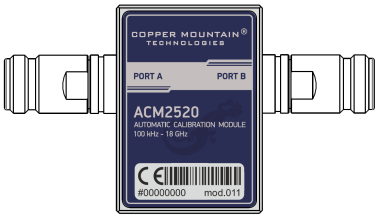
The Modules can be shipped in packages in conditions excluding any exposure to mechanical or package damage during transportation.

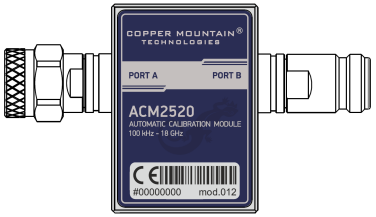
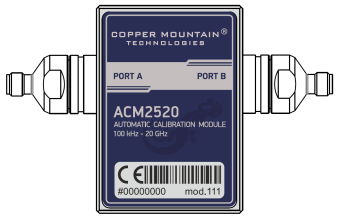
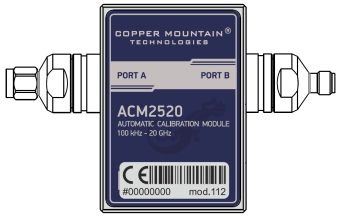
Cargo holds, railway cars, containers, and truck beds, utilized for shipment of the Module should be free from any traces of cement, coal, chemicals, etc. When shipped by air, the products should be kept in aircraft sealed compartments.

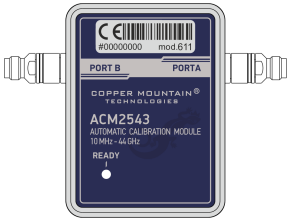
Annex A — Modules Overview

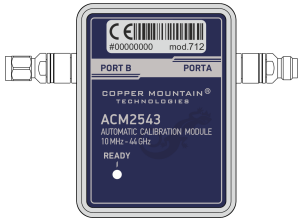
Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM2506 - 011 	20 kHz to 6.5 GHz 2 to 1601 2 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2506 - 012 	20 kHz to 6.5 GHz 2 to 1601 2 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2506 - 111 	20 kHz to 6.5 GHz 2 to 1601 2 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM2506 - 112 	20 kHz to 6.5 GHz 2 to 1601 2 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2509 - 011 	20 kHz to 9 GHz 2 to 1601 2 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2509 - 012 	20 kHz to 9 GHz 2 to 1601 2 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

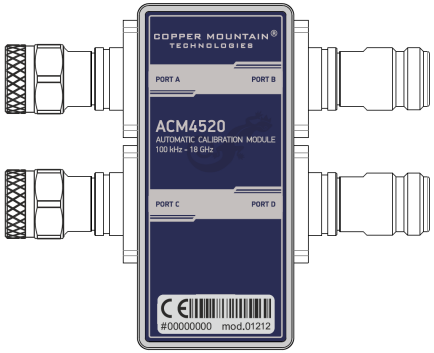
Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM2509 - 111 	20 kHz to 9 GHz 2 to 1601 2 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2509 - 112 	20 kHz to 9 GHz 2 to 1601 2 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2520 - 011 	100 kHz to 18 GHz 2 to 1601 2 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM2520 - 012 	100 kHz to 18 GHz 2 to 1601 2 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2520 - 111 	100 kHz to 20 GHz 2 to 1601 2 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2520 - 112 	100 kHz to 20 GHz 2 to 1601 2 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

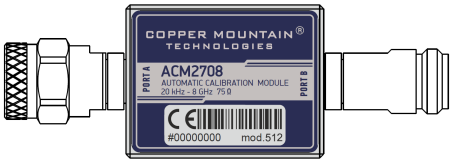
Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM2543 - 611 	10 MHz to 40 GHz 2 to 1601 2 ports 2.92 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2543 - 612 	10 MHz to 40 GHz 2 to 1601 2 ports 2.92 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2543 - 711 	10 MHz to 44 GHz 2 to 1601 2 ports 2.4 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM2543 - 712 	10 MHz to 44 GHz 2 to 1601 2 ports 2.4 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM4509 - 01111 	100 kHz to 9 GHz 2 to 1601 4 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM4509 - 01212 	10 kHz to 9 GHz 2 to 1601 4 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM4509 - 11111 	100 kHz to 9 GHz 2 to 1601 4 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM4509 - 11212 	100 kHz to 9 GHz 2 to 1601 4 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM4520 - 01111 	100 kHz to 20 GHz 2 to 1601 4 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM4520 - 01212 	100 kHz to 20 GHz 2 to 1601 4 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

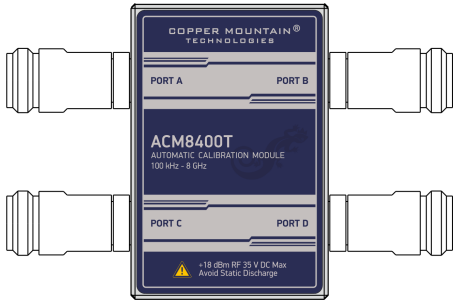
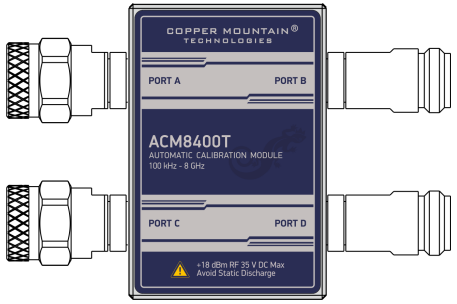
Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM4520 - 11111 	100 kHz to 20 GHz 2 to 1601 4 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM4520 - 11212 	100 kHz to 20 GHz 2 to 1601 4 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

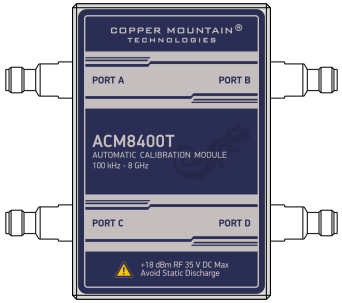
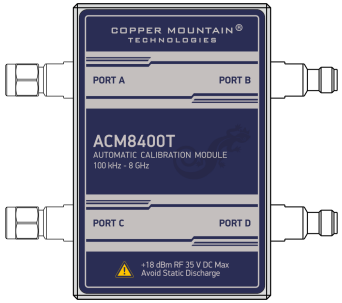
Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM2708 - 511 	20 kHz to 4 GHz 2 to 1601 2 ports type N (75 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM2708 - 512 	20 kHz to 4 GHz 2 to 1601 2 ports type N (75 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM4000T - 511 	20 kHz to 4 GHz 2 to 1601 2 ports type N (75 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM4000T - 512 	20 kHz to 4 GHz 2 to 1601 2 ports type N (75 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM6000T - 011 	20 kHz to 6 GHz 2 to 1601 2 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM6000T - 012 	20 kHz to 6 GHz 2 to 1601 2 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM6000T - 111 	20 kHz to 6 GHz 2 to 1601 2 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM6000T - 112 	20 kHz to 6 GHz 2 to 1601 2 ports 3..5 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM8000T - 011 	100 kHz to 8 GHz 2 to 1601 2 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM8000T - 012 	100 kHz to 8 GHz 2 to 1601 2 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM8000T - 111 	100 kHz to 8 GHz 2 to 1601 2 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM8000T - 112 	100 kHz to 8 GHz 2 to 1601 2 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM8400T - 01111 	100 kHz to 8 GHz 2 to 1601 4 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM8400T - 01212 	100 kHz to 8 GHz 2 to 1601 4 ports type N (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Module	Frequency range Characterization points Number of ports Port connector	Supported calibrations	Features
ACM8400T - 11111 	100 kHz to 8 GHz 2 to 1601 4 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check
ACM8400T -11212 	100 kHz to 8 GHz 2 to 1601 4 ports 3.5 mm (50 Ohm)	Full one-port One-path two-port Full two-port Full three-port Full four-port	Unknown thru Thermal compensation User characterization Automatic orientation Confidence check

Annex B — Instruction for Use of the Protective Housing

Procedure for installing (removing) the protective housing:

1. Unscrew using a PH1(PZ1) screwdriver:
   - 4 pcs. M3×22 screws on the ACM cover. Remove the ACM cover (See figure below).
   - 2 pcs. M2×18 screws and 2pcs. M2×10 screws on the USB connector cover. Remove the cover.

2. Install (remove) the ACM with the USB cable plugged in. The USB cable must be disconnected from the computer. The orientation of the instrument and the legs of the housing must comply with the figure below.

NOTE For the ACM2509, turn the legs over for convenient wrench access to the type N connectors.

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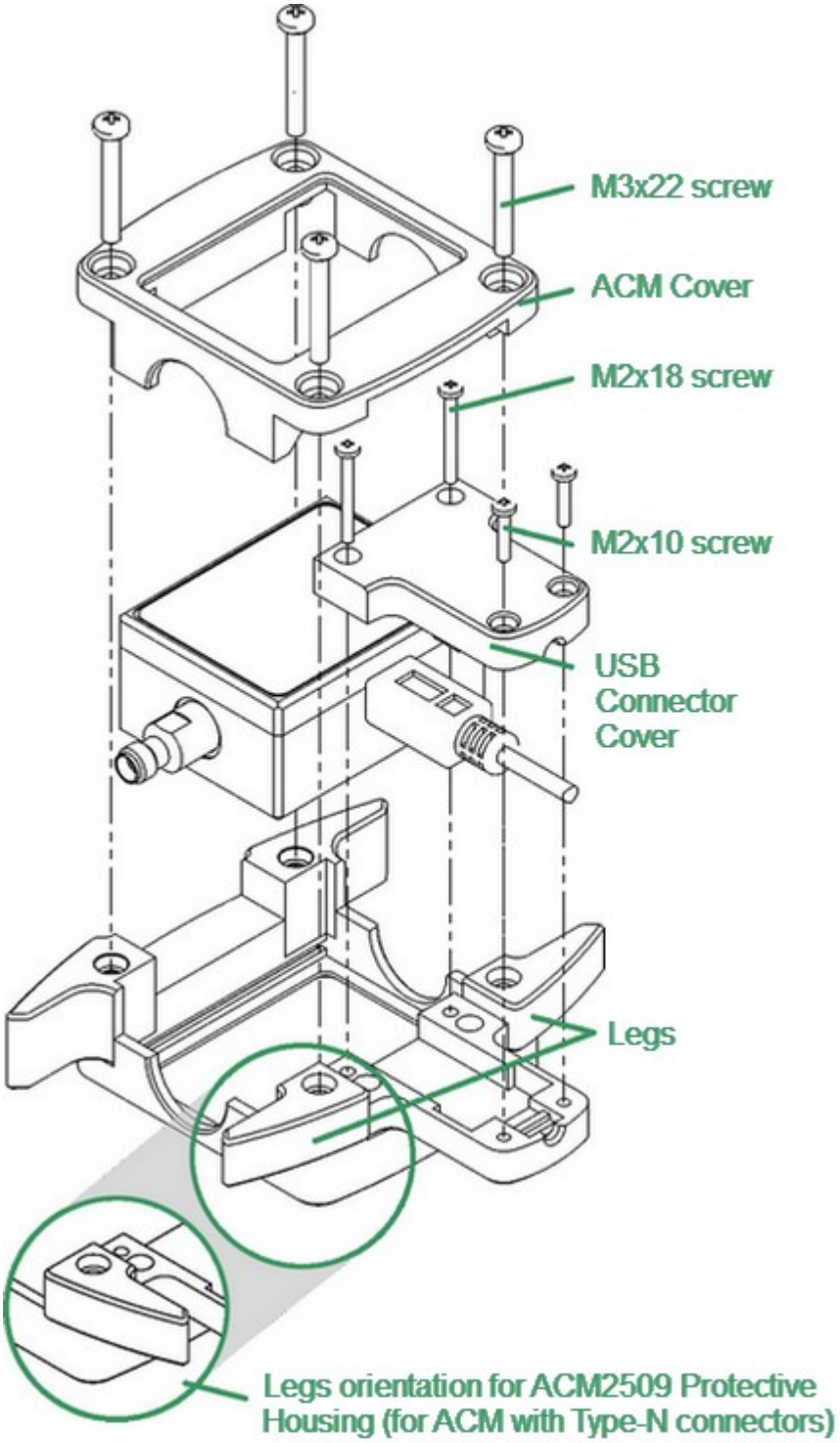
3. Install the USB connector cover, then the ACM cover, using the same screws.

NOTE The head of the screw should be slightly recessed. Tighten without using force, making sure not to allow the material to bulge on opposite side.



Example of housing installation (for ACM2509-011)

Glossary

Prefixes

μ	micro (10^{-6})
m	milli (10^{-3})
k	kilo (10^{3})
M	Mega (10^{6})
G	Giga (10^{9})

Number / Symbols

Ω	ohm
dB	decibel
dBm	decibels above 1 milliwatt
W	Watt
F	Farad
H	Henry
Hz	Hertz
m	meter
sec	second
V	Volt

The following abbreviations are used in this manual:

ACM	Automatic Calibration Module
CMT	Copper Mountain Technologies
DC	Direct current
DUT	Device Under Test
LED	Light-emitting diode
PC	Personal Computer
VNA	Vector Network Analyzer
USB	Universal Serial Bus

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