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Keysight Technologies
Electronic Calibration (ECal) Modules for Vector Network Analyzers

N4690 Series, 2-port Microwave ECal
85090 Series, 2-port RF ECal
N4430 Series, 4-port ECal

Technical Overview



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Introduction

Electronic calibration (ECal) is a precision, single-connection,one-, two-, three-, or four-port calibration technique for your vector network analyzer. ECal modules use fully traceable and verifiable electronic impedance standards. The modules are state-of-the-art, solid-state devices with programmable and highly repeatable impedance states. ECal modules are transfer standards that provide consistent calibrations and eliminate operator errors while bringing convenience and simplicity to your calibration routine. Consistent calibrations provide consistent measurements.

ECal replaces the traditional calibration technique, which uses mechanical standards. With mechanical standards you are required to make numerous connections to the test ports for a single calibration. These traditional calibrations require intensive operator interaction, which is prone to error. With ECal, a full one- to four-port calibration can be accomplished with a single connection to the ECal module and minimal operator interaction. This results in faster and more repeatable calibrations.

Mixed-connector options are available for the 85092C,85093C, 85098C, N4431B and N4432A. The available connectors are Type-N 50 Ω, 3.5 mm, and 7-16.

Control ECal directly from the PNA or ENA

- 300 kHz to 26.5 GHz module
- 10 MHz to 67 GHz module
- Nine connector types available
- Ideal calibration technique for manufacturing
- Mixed-connectors available (Type-N 50 Ω, 3.5 mm and 7-16)

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Accurate Transfer Standards

The ECal modules are transfer standards capable of transferring the factory calibration accuracy to your network analyzer. They are characterized by Keysight Technologies, Inc.using a precision calibration technique (similar in accuracy to TRL) that is traceable to the National Institute of Standards and Technology (NIST). Each calibration module's unique S-parameter data is stored in the module's memory. During calibration, ECal uses this data to calculate the error terms for your network analyzer. All measurements on either insertable or non-insertable devices are traceable to NIST.

Faster Calibration with a Single Connection

Unlike the traditional mechanical technique, ECal only requires one connection to perform a full one- to four-port calibration from the calibration module to the test ports.

By reducing the number of connections required for a calibration, you can

- Calibrate faster, so you save time and make measurements sooner
- Reduce the chance of operator error, for greater confidence in your calibrations
- Reduce the wear on connectors, for lower repair costs on both the test port connectors and calibration standards

Network Analyzer Compatibility

The 85090 family of RF ECal modules provides calibration across the frequency range of the ENA and 8753 series of network analyzers. The N4690 family of microwave ECal modules provides calibrations through 67 GHz for PNA-L and PNA network analyzers. The N4430 family of four-port modules provide calibration for the ENA, PNA, and 4-port PNA-L, and any multiport solutions.

Suggested ECal and network analyzer/firmware compatibility [1]

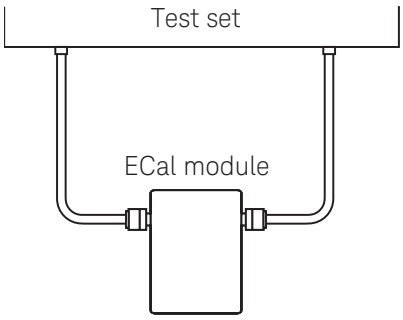
Keysight VNA model number	Ecal module model number
ENA Series [3]	N4430 Series, 85090 Series, N4690 Series [2]
ENA-L Series [4]	N4430 Series, 85090 Series
PNA Series [5]	N4430 Series, N4690 Series
PNA-L Series [6]	N4430 Series, N4690 Series

1. For complete compatibility refer to the ECal Reference Guide (publication N4693-90001).
2. Exception: the N4693A and N4694A are not supported on the ENA.
3. ENA series consists of E5070/1.
4. ENA-L series consists of E5061/2.
5. The PNA Series Network Analyzers consists of E8361/2/3/4. Please note: RF PNA Series E8356/7/8, E8801/2/3 and N3381/2/3 have been discontinued.
6. PNA-L series consists of N5230.

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Simple Non-Insertable Calibrations

Most common RF and microwave components have non-insertable connectors; for example, devices with female connectors on both ports. These devices require an adapter removal calibration, which adds an uncertainty factor to the measurement. Most modern vector network analyzers use an adapter removal technique, which compensates for adapter caused errors.



The simplest and fastest non-insertable calibration method uses an ECal module with connectors that match your device, and the same calibration method as insertable devices. Simply order your ECal module with connectors that match your device under test:

- Option 00M, male connectors on both ports
- Option 00F, female connectors on both ports.
- Option M0F with one male and one female connector.

Perform adapter removal calibrations faster

Some analyzers, such as later versions of the 8753 and 8720, offer adapter removal calibration for non-insertable and mixed connector measurement capability. Since this method requires two full two-port calibrations, it is often time consuming and prone to operator errors. Using ECal to perform the two-port calibrations addresses both of these concerns by reducing the calibration time and the number of connections, simplifying the overall adapter removal process.

Perform a user-characterization

Normally, when you perform a calibration with an ECal module, the error terms for a calibration are computed using the factory characterization (data) stored in the module. User-characterization allows you to change the characterization of the module in two ways:

- Change the connector configuration: allows you to add an adapter or fixture to the test port of the module and embed the effects into the characterization of the module. The result of the new characterization extends the reference plane from one or more of the module's test ports to those on the adapter (or fixture).
- Modify the state settings: allows you to specify the number of data points (1601 maximum) or other stimulus settings the module uses to perform a calibration.

When you perform a user-characterization, the factory characterization data remains stored in the module's memory. At calibration, you can select the factory characterization or any of the user-defined characterizations stored in the module. The module can store up to five user-defined characterizations (in addition to the factory characterization data).

User-characterization is available with PNA and ENA Series Network Analyzers.

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Input Power Level

Before performing a calibration, make sure the input power and DC levels do not exceed the values indicated in the table below.

Input power limits

	ECal module series			
Parameter	**8509x**	**N4431x**	**N4432A/N4433A**	**N469x**
Typical maximum input power [1, 2]	+9.0 dBm	+7.0 dBm	–7.0 dBm	–5.0 dBm
Typical maximum DC level applied to test port	± 20 volts	± 3 volts	± 3 volts	± 10 volts
Typical damage level	+20.0 dBm	+20.0 dBm	+20.0 dBm	+10.0 dBm

Operating temperature

The temperature of the ECal module must be within the following temperature range to meet the operating specifications.

- 8509x Series: +20 to +30 °C
- N443xA/B Series: +20 to +30 °C
- N469xA/B Series: +20 to +26 °C

Characteristic Performance

Characteristic performance for RF and microwave ECal modules are provided in the following tables, which describe non-warranted performance that most units exhibit.

8509x Series

85091C (7 mm) [1]	**Frequency range**				
Parameter	**300 kHz to 10 MHz**	**10 MHz to 1 GHz**	**1 to 3 GHz**	**3 to 6 GHz**	**6 to 9 GHz**
Directivity (dB)	45	52	52	50	45
Source match (dB)	36	45	44	41	34
Reflection tracking (± dB)	0.1	0.04	0.04	0.07	0.1
Transmission tracking (± dB) [2]	0.08	0.05	0.05	0.07	0.15
Load match (dB) [2]	40	46	45	43	38
85092C (Type-N 50Ω) [1]	**Frequency range**				
Parameter	**300 kHz to 10 MHz**	**10 MHz to 1 GHz**	**1 to 3 GHz**	**3 to 6 GHz**	**6 to 9 GHz**
Directivity (dB)	45	52	52	49	45
Source match (dB)	36	45	44	41	36
Reflection tracking (± dB)	0.1	0.04	0.04	0.06	0.07
Transmission tracking (± dB) [2]	0.12	0.05	0.06	0.11	0.17
Load match (dB) [2]	36	41	45	40	37
85093C (3.5 mm) [1]	**Frequency range**				
Parameter	**300 kHz to 10 MHz**	**10 MHz to 1 GHz**	**1 to 3 GHz**	**3 to 6 GHz**	**6 to 9 GHz**
Directivity (dB)	45	52	52	50	47
Source match (dB)	36	44	44	39	34
Reflection tracking (± dB)	0.1	0.03	0.04	0.05	0.07
Transmission tracking (± dB)	0.13	0.05	0.05	0.10	0.16
Load match (dB)	36	42	45	42	39

1. When applied power exceeds +9 dBm, calibration results will be degraded from the performance indicated in this table.
2. Values based on using the network analyzer N5231A Option 200

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85096C (Type-N 75Ω) [1]	Frequency range			
Parameter	**300 kHz to 10 MHz**	**10 to 300 MHz**	**300 MHz to 1.3 GHz**	**1.3 to 3 GHz**
Directivity (dB)	45	50	48	43
Source match (dB)	36	48	45	38
Reflection tracking (± dB)	0.1	0.03	0.06	0.10
Transmission tracking (± dB) [2]	0.13	0.05	0.06	0.10
Load match (dB) [2]	36	42	41	37

1. When applied power exceeds +9 dBm, calibration results will be degraded from the performance indicated in this table.
2. Values based on using the network analyzer E5061B Option 237.

85098C (7-16) [1]	Frequency range				
Parameter	**300 kHz to 10 MHz**	**10 MHz to 1 GHz**	**1 to 3 GHz**	**3 to 6 GHz**	**6 to 7.5 GHz**
Directivity (dB)	45	47	47	46	45
Source match (dB)	36	43	43	38	37
Reflection tracking (± dB)	0.1	0.03	0.03	0.05	0.06
Transmission tracking (± dB) [2]	0.13	0.06	0.07	0.12	0.14
Load match (dB) [2]	36	40	38	36	34

1. When applied power exceeds +9 dBm, calibration results will be degraded from the performance indicated in this table.
2. Values based on using the network analyzer N5231A Option 200.

85099C (Type-F) [1,2]	Frequency range			
Parameter	**300 kHz to 10 MHz**	**10 to 300 MHz**	**300 MHz to 1.3 GHz**	**1.3 to 3 GHz**
Directivity (dB)	45	50	48	43
Source match (dB)	36	48	45	38
Reflection tracking (± dB)	0.10	0.03	0.07	0.15
Transmission tracking (± dB) [3]	0.14	0.05	0.07	0.11
Load match (dB)[3]	36	42	41	36

1. When mated with male connectors with a 0.77 mm (.030 in) to 0.86 (0.34) pin diameter
2. When applied power exceeds +9 dBm, calibration results will be degraded from the performance indicated in this table.
3. Values based on using the network analyzer E5061B Option 237.

N4431B (3.5 mm)

The characteristic performance in the following table applies to N4431B Option 010 (3.5 mm female connectors on all ports). The data describes performance when measuring “thru path” A-B, C-D, A-D and B-C.

N4431B Option 010 [1]	Frequency range						
Parameter	**9 kHz [2] to 10 MHz**	**10 MHz to 1 GHz**	**1 to 3 GHz**	**3 to 6 GHz**	**6 to 8 GHz**	**8 to 9 GHz**	**9 to 13.5 GHz**
Directivity (dB)	45	53	52	48	46	44	40
Source match (dB)	36	50	47	45	44	43	32
Reflection tracking (± dB)	0.10	0.03	0.03	0.04	0.04	0.05	0.10
Transmission tracking (± dB) [3]	0.10	0.04	0.06	0.11	0.14	0.15	0.30
Load match (dB) [3]	38	45	45	40	38	36	32

1. When applied power exceeds +7 dBm, calibration results will be degraded from the performance indicated in this table.
2. Performance from 9 kHz to 300 kHz is valid only for the E5071C ENA network analyzer with firmware version A.09.10 or higher.
3. Values based on using the network analyzer N5231A Option 400.

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The characteristic performance in the following table applies to N4431B Option 010 (3.5 mm female connectors on all ports). The data describes performance when measuring "thru path" A-C and B-D.

N4431B Option 010 [1]	Frequency range						
Parameter	9 kHz [2] to 10 MHz	10 MHz to 1 GHz	1 to 3 GHz	3 to 6 GHz	6 to 8 GHz	8 to 9 GHz	9 to 13.5 GHz
Directivity (dB)	45	53	52	48	46	44	40
Source match (dB)	36	50	47	45	44	43	32
Reflection tracking (± dB)	0.10	0.03	0.03	0.04	0.04	0.05	0.10
Transmission tracking (± dB) [3]	0.10	0.04	0.06	0.11	0.14	0.15	0.30
Load match (dB) [3]	38	45	45	40	38	36	32

N4431B (Type-N 50 Ω)

The characteristic performance in the following table applies to N4431B Option 020 (type-N female connectors on all ports). The data describes performance when measuring "thru path" A-B, C-D, A-D and B-C.

N4431B Option 020 [1]	Frequency range						
Parameter	9 kHz [2] to 10 MHz	10 MHz to 1 GHz	1 to 3 GHz	3 to 6 GHz	6 to 8 GHz	8 to 9 GHz	9 to 13.5 GHz
Directivity (dB)	45	53	52	46	44	42	38
Source match (dB)	36	47	43	42	40	39	31
Reflection tracking (± dB)	0.10	0.03	0.04	0.04	0.05	0.06	0.11
Transmission tracking (± dB) [3]	0.10	0.04	0.07	0.12	0.16	0.18	0.45
Load match (dB) [3]	38	45	44	39	37	35	31

The characteristic performance in the following table applies to N4431B Option 020 (type-N female connectors on all ports). The data describes performance when measuring "thru path" A-C and B-D.

N4431B Option 020 [1]	Frequency range						
Parameter	9 kHz [2] to 10 MHz	10 MHz to 1 GHz	1 to 3 GHz	3 to 6 GHz	6 to 8 GHz	8 to 9 GHz	9 to 13.5 GHz
Directivity (dB)	45	53	52	46	44	42	38
Source match (dB)	36	47	43	42	40	39	31
Reflection tracking (± dB)	0.10	0.03	0.04	0.04	0.05	0.06	0.11
Transmission tracking (± dB) [3]	0.10	0.04	0.06	0.11	0.14	0.15	0.31
Load match (dB)[3]	38	45	44	39	37	55	31

1. When applied power exceeds +7 dBm, calibration results will be degraded from the performance indicated in this table.
2. Performance from 9 kHz to 300 kHz is valid only for the E5071C ENA network analyzer with firmware version A.09.10 or higher.
3. Values based on using the network analyzer N5231A Option 400.

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N4432A (Type-N 50 Ω)

The characteristic performance in the following table applies to N4432A Option 020 (type-N female connectors on all ports).

N4432A Option 020 (type-N female connectors on all ports) Option 020 [1]	Frequency range				
Parameter	**10 MHz to 5 GHz**	**10 MHz to 5 GHz**	**5 to 9 GHz**	**9 to 13.5 GHz**	**13.5 to 18 GHz**
Directivity (dB)	45	50	47	41	40
Source match (dB)	35	41	37	34	34
Reflection tracking (± dB)	0.10	0.06	0.10	0.15	0.14
Transmission tracking (± dB) [3]	0.18	0.05	0.10	0.17	0.21
Load match (dB) [3]	35	42	39	35	33

N4433A (3.5 mm)

The characteristic performance in the following table applies to N4433A Option 010 (3.5 mm female connectors on all ports).

N4433A Option 010 (3.5 mm female connectors on all ports) 020 [1]	Frequency range				
Parameter	**300 kHz to 10 MHz**	**10 MHz to 5 GHz**	**5 to 9 GHz**	**9 to 13.5 GHz**	**13.5 to 20 GHz**
Directivity (dB)	45	50	47	45	40
Source match (dB)	36	42	39	37	31
Reflection tracking (± dB)	0.10	0.06	0.09	0.12	0.23
Transmission tracking (± dB) [3]	0.18	0.05	0.09	0.12	0.23
Load match (dB) [3]	35	42	39	38	32

1. When applied power exceeds –7 dBm, calibration results will be degraded from the performance indicated in this table.
2. Values based on using the network analyzer N5232A Option 400.

N469xA/B/C Series

N4690C Option 020 (Type-N 50Ω) [1]	Frequency range					
Parameter	**300 kHz to 2 MHz**	**2 to 10 MHz**	**10 to 500 MHz**	**500 MHz to 2 GHz**	**2 to 10 GHz**	**10 to 18 GHz**
Directivity (dB)	30	40	45	48	44	42
Source match (dB)	28	35	40	43	40	35
Reflection tracking (± dB)	0.12	0.07	0.05	0.03	0.03	0.05
Transmission tracking (± dB)	0.37 [2]	0.08 [2]	0.10 [3]	0.04 [3]	0.05 [3]	0.08 [3]
Load match (dB)	26 [2]	37 [2]	33 [3]	42 [3]	39 [3]	34 [3]

N4691B (3.5 mm) [1]	Frequency range						
Parameter	**300 kHz to 2 MHz**	**2 to 10 MHz**	**10 to 500 MHz**	**500 to 2 GHz**	**2 to 10 GHz**	**10 to 20 GHz**	**20 to 26.5 GHz**
Directivity (dB)	31	41	46	52	48	46	44
Source match (dB)	29	36	41	47	45	42	40
Reflection tracking (± dB)	0.11	0.06	0.05	0.02	0.03	0.04	0.05
Transmission tracking (± dB)	0.37 [2]	0.08 [2]	0.09 [3]	0.03 [3]	0.04 [3]	0.06 [3]	0.08 [3]
Load match (dB)	27 [2]	37 [2]	34 [3]	46 [3]	43 [3]	40 [3]	38 [3]

1. When applied power exceeds –5 dBm, calibration results will be degraded from the performance indicated in this table.
2. Values based on using the network analyzer N5222A Option 200.
3. Values based on using the network analyzer N5222A Option 200.

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N4692A (2.92 mm) [1]	Frequency range					
Parameter	10 to 45 MHz [2]	45 to 200 MHz	200 MHz to 2 GHz	2 to 20 GHz	20 to 30 GHz	30 to 40 GHz
Directivity (dB)	35	41	45	42	39	38
Source match (dB)	30	36	36	35	30	29
Reflection tracking (± dB)	0.10	0.08	0.08	0.08	0.10	0.10
Transmission tracking (± dB) [3]	0.15	0.11	0.09	0.11	0.14	0.15
Load match (dB) [3]	29	34	35	33	28	27

N4693A (2.4 mm) [1]	Frequency range						
Parameter	10 to 45 MHz [2]	45 to 200 MHz	200 MHzto 2 GHz	2 to 10 GHz	10 to 20 GHz	20 to 40 GHz	40 to 50 GHz
Directivity (dB)	32	42	51	49	45	41	36
Source match (dB)	25	44	46	42	37	35	32
Reflection tracking (± dB)	0.05	0.03	0.03	0.04	0.05	0.06	0.08
Transmission tracking (± dB) [3]	0.12	0.06	0.04	0.05	0.07	0.10	0.14
Load match (dB) [3]	24	42	45	40	35	33	30

1. When applied power exceeds –5 dBm, calibration results will be degraded from the performance indicated in this table.
2. Based on typical performance.
3. Values based on using the network analyzer N5225A Option 200.

N4694A (1.85 mm) [1]	Frequency range								
Parameter	10 to 45 MHz [2]	45 to 200 MHz	200 MHz to 2 GHz	2 to 20 GHz	20 to 30 GHz	30 to 40 GHz	40 to 50 GHz	50 to 60 GHz	70 to 67 GHz
Directivity (dB)	33	41	46	47	46	44	42	41	38
Source match (dB)	25	38	38	39	35	34	33	30	27
Reflection tracking (± dB)	0.05	0.04	0.04	0.04	0.05	0.06	0.07	0.08	0.09
Transmission tracking (± dB) [3]	0.15	0.08	0.06	0.06	0.08	0.09	0.11	0.12	0.015
Load match (dB) [3]	24	36	36	37	33	32	31	28	26

1. When applied power exceeds –5 dBm, calibration results will be degraded from the performance indicated in this table.
2. Based on typical performance.
3. Values based on using the network analyzer N5225A Option 200.

N4696B (7 mm) [1]	Frequency range					
Parameter	300 kHz to 2 MHz	2 to 10 MHz	10 MHz to 500 MHz	500 MHz to 2 GHz	2 to 10 GHz	10 to 18 GHz
Directivity (dB)	30	40	46	45	47	42
Source match (dB)	28	35	40	40	42	36
Reflection tracking (± dB)	0.12	0.07	0.05	0.03	0.03	0.05
Transmission tracking (± dB)	0.37 [2]	0.07 [2]	0.10 [3]	0.04 [3]	0.04 [3]	0.08 [3]
Load match w/ECal thru (dB)	26 [2]	37 [2]	33 [3]	39 [3]	41 [3]	34 [3]

1. When applied power exceeds –5 dBm, calibration results will be degraded from the performance indicated in this table.
2. Values based on using the network analyzer N5231A Option 200.
3. Values based on using the network analyzer N5222A Option 200.

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Ordering Information

Select an ECal module based on the connector type required and the frequency range of your vector network analyzer (refer to table below).

ECal modules and available options

2-port

Connector type	Frequency range	ECal module model number	Available options
Type-F	300 kHz to 3 GHz	85099C	00A, 00F, 00M, UK6, M0F
Type-N 50 Ω	300 kHz to 9 GHz	85092C	00A, 00F, 00M, UK6, 1A7, A6J, M0F, mixed-connectors
Type-N 50 Ω	300 kHz to 18 GHz	N4690C	00A, 00F, 00M, UK6, 1A7, A6J, M0F
Type-N 75 Ω	300 kHz to 3 GHz	85096C	00A, 00F, 00M, UK6, M0F
3.5 mm	300 kHz to 9 GHz	85093C	00A, 00F, 00M, UK6, 1A7, A6J, M0F, mixed-connectors
3.5 mm	300 kHz to 26.5 GHz	N4691B	00A, 00F, 00M, UK6, 1A7, A6J, M0F
7 mm	300 kHz to 9 GHz	85091C	UK6, 1A7, A6J
7 mm	300 kHz to 18 GHz	N4696B	UK6, 1A7, A6J
7-16	300 kHz to 7.5 GHz	85098C	00A, 00F, 00M, UK6, M0F, mixed-connectors
2.92 mm	10 MHz to 40 GHz	N4692A	00A, 00F, 00M, UK6, 1A7, A6J, M0F
2.4 mm	10 MHz to 50 GHz	N4693A	00A, 00F, 00M, UK6, 1A7, A6J, M0F
1.85 mm	10 MHz to 67 GHz	N4694A	00A, 00F, 00M, UK6, 1A7, A6J, M0F

4-port

Connector type	Frequency range	ECal module model number	Available options
3.5 mm or Type-N 50 Ω	9 kHz to 13.5 GHz [1]	N4431B	010, 020, UK6, 1A7, A6J, mixed-connectors
Type-N 50 Ω	300 kHz to 18 GHz	N4432A	020, mixed-connectors
3.5 mm	300 kHz to 20 GHz	N4433A	010

1. Performance from 9 kHz to 300 kHz is valid only for the E5071C ENA network analyzer with firmware version A.09.10 or higher.

Options

Option	Description
00F	Replace f-m connectors on ECal module(s) with f-f connectors
00M	Replace f-m connectors on ECal module(s) with m-m connectors
00A	Adds male-to-male and female-to-female adapters (also adds a 5/16" 90 N-cm (8 in-lb) torque wrench to 3.5 mm modules)
1A7	ISO 17025 compliant calibration
A6J	ANSI Z540 compliant calibration
UK6	Commercial calibration certificate with measured data
M0F	f-m connectors on ECal module(s)
010	Four female, 3.5 mm connectors
020	Four female, Type-N 50 ohm connectors

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Mixed-connector options

2-port (85092C/3C/8C ECal modules only)

	Port A option			Port B option					
Model number	**Type**	**(f)**	**(m)**	**Type**	**(f)**	**(m)**	**Type**	**(f)**	**(m)**
85092C	Type-N 50 Ω	103	104	3.5 mm	201	202	7-16 [1]	205	206
85093C	3.5 mm	101	102	Type-N 50 Ω	203	204	7-16 [1]	205	206
85098C	7-16 [1]	105	106	3.5 mm	201	202	Type-N 50 Ω	203	204

4-port (N4431B ECal module only)

Connector type	Port A option	Port B option	Port C option	Port D option
3.5 mm (f)	101	201	301	401
3.5 mm (m)	102	202	302	402
Type-N 50 Ω (f)	103	203	303	403
Type-N 50 Ω (m)	104	204	304	404
7-16 (f) [1]	105	205	305	405
7-16 (m) [1]	106	206	306	406

1. Limits ECal module high frequency to 7.5 GHz.

4-port (N4432B ECal module only)

Connector type	Port A option	Port B option	Port C option	Port D option
3.5 mm (f)	101	201	301	401
3.5 mm (m)	102	202	302	402
Type-N 50 Ω (f)	103	203	303	403
Type-N 50 Ω (m)	104	204	304	404

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