

Keysight Technologies

U9391C/F/G Comb Generators

U9391C (10 MHz to 26.5 GHz)

U9391F (10 MHz to 50 GHz)

U9391G (10 MHz to 67 GHz)

Technical Overview



Key Features

- Excellent amplitude and phase flatness enable it to be used as a precision calibration phase reference standard for the NVNA
- NIST referenced phase calibration guarantees a reliable reference to international standards
- Embedded calibration data can be easily accessed via the plug-and-play USB interface
- The USB interface facilitates frequency divider control and calibration data retrieval via the PNA-X
- Rugged 1.85-mm, 2.4-mm, and 3.5-mm bulk-head connectors guarantee high repeatability throughout multiple connects and disconnects
- Sine to square wave converter provided as standard accessory (U9391F/G only) ensures the comb generator functions at its optimum level for output frequencies above 26.5 GHz
- Handgrip (U9391G only) designed for better gripping and as heat insulator for user handling

Description

The Keysight Technologies, Inc. U9391C/F/G comb generators were developed to provide precision phase calibration, referenced to the National Institute of Standards and Technology (NIST) standard, for non-linear measurements using the PNA-X nonlinear vector network analyzer (NVNA)¹. NVNA component characterization software converts a 4-port PNA-X with Option 510 into an innovative, high-performance, non-linear network analyzer which uses U9391C/F/G comb generators as a precision phase calibration standard. Comb generators generate frequency harmonics at integer multiples from an RF input signal. Generally, comb generators available in the open market today are made with SRD diodes, U9391C/F/G comb generators are based on Keysight InP MMIC technology² to ensure superior phase stability of the combs.

U9391C/F/G modules are solid state devices which provide excellent phase and amplitude flatness in the combs making them ideal for use in phase calibration applications. A built-in frequency divider, selectable via the PNA-X, reduces the noise of the combs. You can set drive frequency at 1, 2, 4, 8 or 16 times the pulse repetition frequency (PRF). Combining a frequency divider with a wide input signal frequency range allows for a broad range of possible harmonics spacing, making this suitable for characterizing non-linear devices. This module has a trigger output which enables synchronization with the pulse's repetition frequency. Calibration data stored inside the U9391C/F/G can be accessed directly by the PNA-X via the USB interface for phase calibration. The comb generator comes with the option of female or male output connectors.

Keysight's new patented-pending comb generators offers the advantage of wide bandwidth output (10 MHz - 26.5 GHz, 10 MHz to 50 GHz, and 10 MHz to 67 GHz) and small minimum tone spacing (10 MHz). When driven by low phase noise sources, this comb generator will operate at frequencies lower than 10 MHz, but performance is not guaranteed. The input power and fundamental frequency have lower sensitivity than other comb generators. This means a comb generator calibrated at a single power level and frequency can be used across a wide range of input power levels and frequencies.

Keysight characterizes the U9391C/F/G comb generators' phase standard using

1. NOTE: The U9391C/F/G was designed for use with the PNA-X ONLY.

2. Indium phosphide monolithic microwave integrated circuit

Accurate transfer of NIST standard

a precision calibration technique that is traceable to NIST. Each comb generator's amplitude and phase data is stored in the module's memory. The N5242A-510 NVNA component characterization software uses the phase data from the U9391C/F/G to calculate the non-linear error terms for the PNA-X network analyzers.

Applications

Network analyzer compatibility

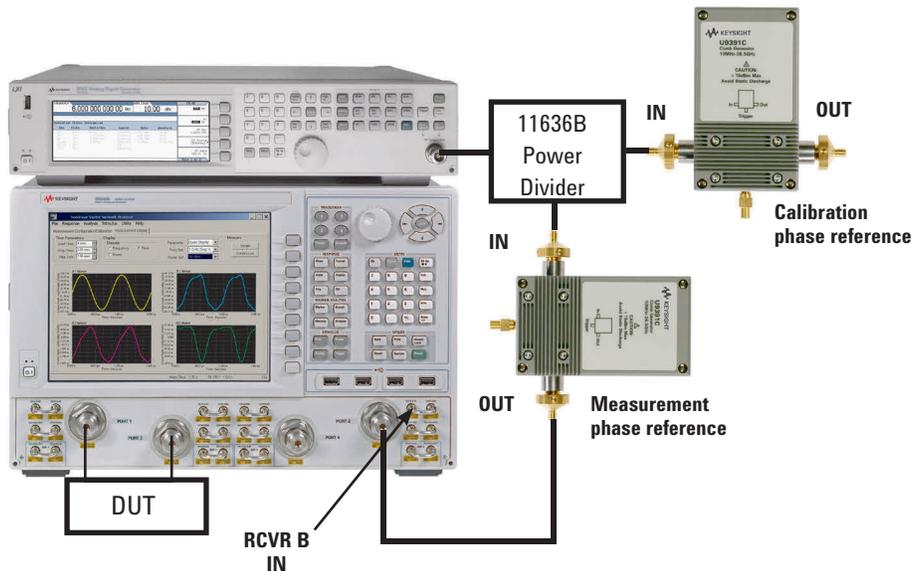
The U9391C comb generator is controlled by the N5242A 26 GHz PNA-X network analyzer via a USB connection (options required: 400, 419, 080, 510). The U9391F comb generator can be used with the N5245A 50 GHz PNA-X network analyzer via USB connection (options required: 400, 419, 080, 510). The U9391G comb generator can be used with the N5247A 67 GHz PNA-X network analyzer via USB connection (options required: 400, 419, 080, 510). The N5242A/45A/47A PNA-X network analyzers can be upgraded to perform nonlinear component characterization.

Comb generator and PNA-X configurations

Two units of U9391C/F/G are required to carry out non-linear measurements. One unit is used as the phase reference module and the second unit as the phase calibration module.

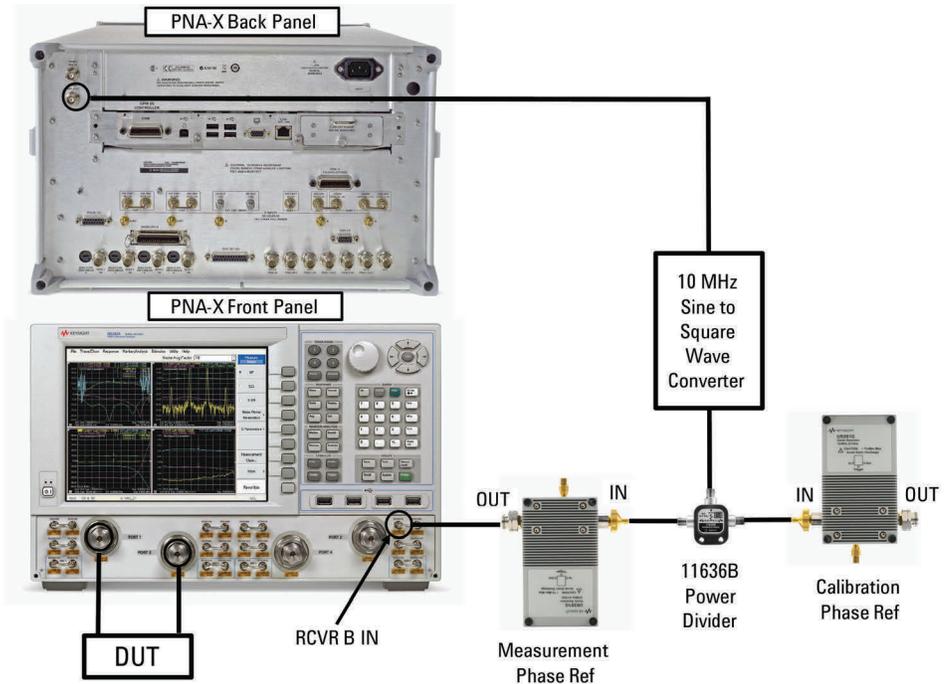
The U9391C/F/G units need to be powered by separate power supplies. The NVNA software automatically controls the U9391C/F/G units via USB after they have been designated as phase reference and calibration modules respectively.

The phase calibration procedure is carried out by following the on-screen instructions on the PNA-X. After completing the calibration, the U9391C/F/G unit used for phase calibration can be disconnected. The other unit will be used as the phase reference and must remain connected while the measurement is carried out.



Alternative configuration with squaring unit

If a signal generator is not available, the 10 MHz reference output on the back panel of the PNA-X can be used as a signal source. However, the U9391-60009 sine to square wave converter is needed as the comb generator will not function at its optimum level for output frequencies above 26.5 GHz, with a sine wave input of less than 100 MHz. Therefore, U9391-60009 is included as a standard accessory for U9391F and U9391G.



DC power supply compatibility

The U9391C/F/G can be powered by any DC power supply that is capable of supplying at least 300 mA (nominal) at $15 \pm 10\%$ Vdc¹ (via the banana plug cables provided).

Recommended DC power supply for U9391C/F:
 Recommended DC power supply for U9391G:
 Compatible DC power supply:

E3620A
 E3615A
 All E36XXA series power supply (except E3612A and E3614A)

U9391C/F/G Drive Power Supply Specification

Specifications	U9391C/F	U9391G
Voltage	+15V +/- 10% Vdc	+15V +/- 10% Vdc
Current	300 mA (nominal)	850 mA (nominal)

1. Current drawn will change when drive voltage changes.

Options

Output connectors Specifications 1

Option FFF – female (output port)

Option FFM – male (output port)

Specifications refer to the performance standards or limits against which the U9391C/F/G comb generators are tested.

Typical characteristics are included for additional information only and they are not specifications. These are denoted as "typical", "nominal" or "approximate" and are printed in italic.

Specifications		U9391C	U9391F	U9391G
Output frequency range		10 MHz to 26.5 GHz	10 MHz to 50 GHz	10 MHz to 67 GHz
Input frequency range		10 MHz to 6 GHz	10 MHz to 6 GHz	10 MHz to 6 GHz
Input power range		-15 to +15 dBm	-15 to +15 dBm	-15 to +15 dBm
Min output power per picket	at 10 MHz Input PRF	-80 dBm	-95 dBm	-100 dBm
Amplitude flatness vs. output frequency	at 10 MHz Input PRF	< 12 dB	< 25 dB	< 40 dB
Amplitude flatness vs. input power		0.1dB (typical)	0.5dB (typical)	1.0 dB (typical)
Phase flatness/degree	10 MHz to 3 GHz	± 8.5	+ 10 /- 10	+ 10 /- 10
	3 GHz to 20 GHz	± 6.5	+ 10 /- 10	+ 10 /- 10
	20 GHz to 26.5 GHz	± 8.5	+ 10 /- 10	+ 10 /- 10
	26.5 GHz to 28 GHz		+ 10 /- 10	+ 20 /- 10
	28 GHz to 38 GHz		+20 / -10	+20 / -10
	38 GHz to 45 GHz		+20 / -15	+20 / -15
	45 GHz to 50 GHz		+20 / -15	+20 / -15
	50 GHz to 67 GHz			+35 / - 35
Pulse width		< 23 ps	< 23 ps	< 23 ps
Divide ratio		1,2,4,8,16	1,2,4,8,16	1,2,4,8,16
Input return loss, S11	10 MHz to 6 GHz	> 10 dB	> 10 dB	> 10 dB
Output return loss, S22	10 MHz to 10 GHz	> 10 dB	> 10 dB	> 10 dB
	10 GHz to 20 GHz	> 10 dB	> 10 dB	> 10 dB
	20 GHz to 26.5 GHz	> 10 dB	> 7 dB	> 7 dB
	26.5 GHz to 45 GHz		> 7 dB	> 7 dB
	45 GHz to 50 GHz		> 5 dB	> 5 dB
	50 GHz to 67 GHz			> 5 dB

Environmental Specifications

U9391C/F/G comb generators are designed to fully comply with Keysight's product operating environment specifications. The following are the summarized environmental specifications for these products.

Specifications	Limits
Temperature	
Operating	0 to +40 °C
Storage	-40 to +70 °C
Error corrected range	23 °C ±3 °C
Cycling	-65 to +85 °C, 10 cycles at 20 °C per minute. 20 minutes dwell time per MIL-STD-883F, Method 1010.8, Condition C (modified)
Relative humidity	
Operation	50% to 95% RH at 40 °C, 24 hours cycling, repeated 5 times
Storage	90% RH at 65 °C, one 24 hour cycle
Shock	
End-use handling shock	Half-sine waveform, 2-3 ms duration, 60 in/s (1.6 ms) delta-V
Transportation shock	Trapezoidal waveform, 18-22 ms duration, 337 in/s (8.56 ms) delta-V
Vibration	
Operating	Random: 5 to 500 Hz, 0.21 grms, 10 min/axis
Survival	Random: 5 to 500 Hz, 2.09 grms, 10 min/axis Swept sine: 5 to 500 Hz, 0.5 grms, 10 min/axis, 4 resonance search, 10 min dwell
Altitude	
Operating	< 4,572 meters (15,000 ft)
Storage	< 15,000 meters (50,000 ft)
ESD immunity	
Direct discharge ¹	8.0 kV per IEC 61000-4-2
Air discharge	15 kV per IEC 61000-4-2

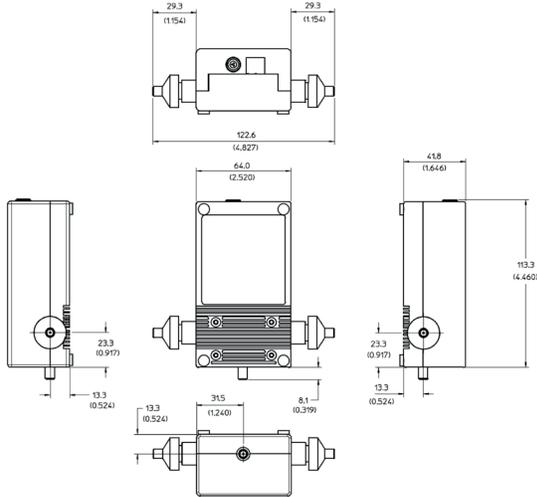
1. To outer conductor

1. Note: The U9391C/F/G was specially designed for use with the PNA-X ONLY.

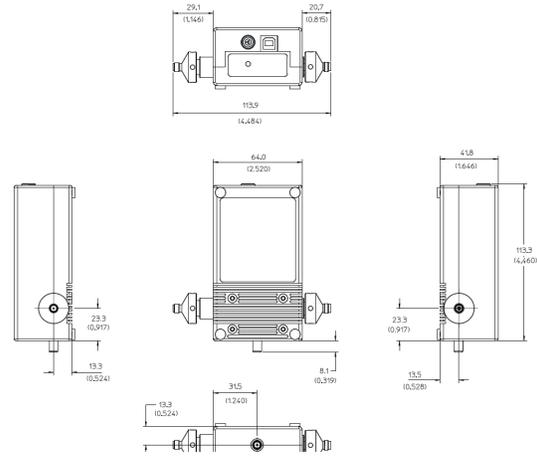
Mechanical Dimensions

Specifications	U9391C/F/G	
Pin Depth	Input	0 to -0.0508 mm (0 to -0.0020")
	Output	0 to -0.0508 mm (0 to -0.0020")
	Trigger	0 to -0.1270 mm (0 to -0.0050")
Net weight	U9391C/F	U9391G
	0.370 kg	0.435 kg

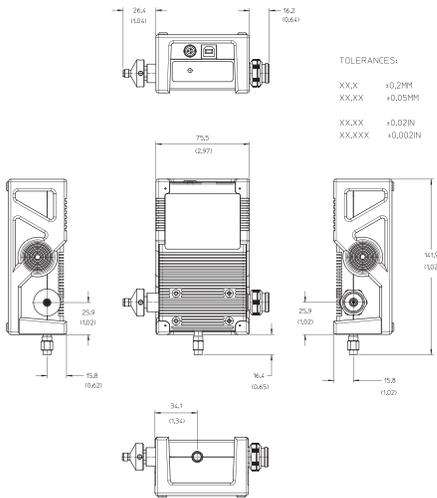
Physical weight of U9391C/F/G



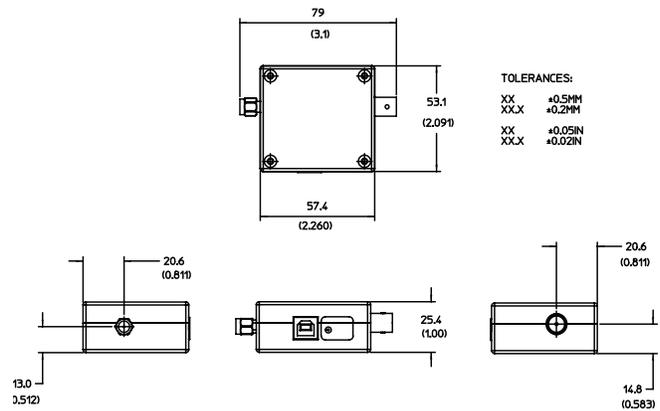
Mechanical dimension for U9391C



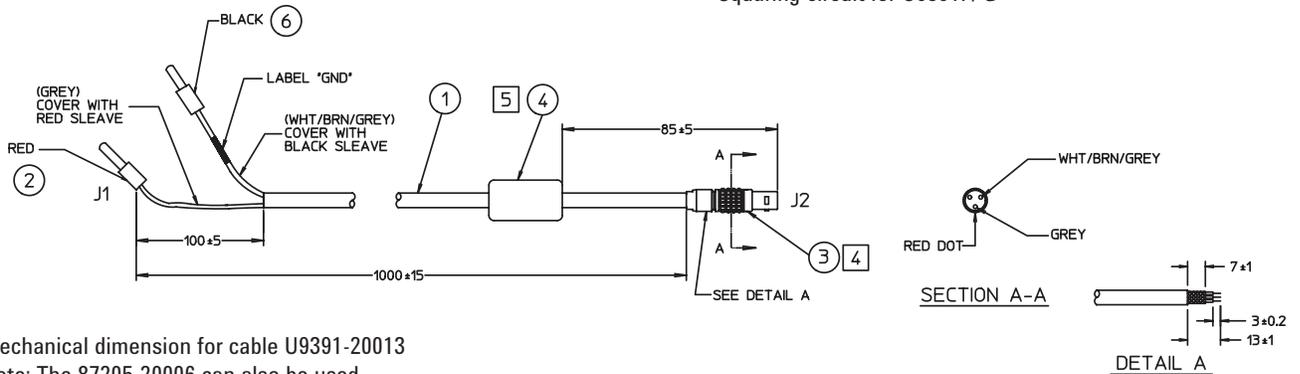
Mechanical dimension for U9391F



Mechanical dimension for U9391G



Mechanical dimension for U9391-60009 Squaring circuit for U9391F/G



Mechanical dimension for cable U9391-20013
Note: The 87205-20006 can also be used.

Typical Performance

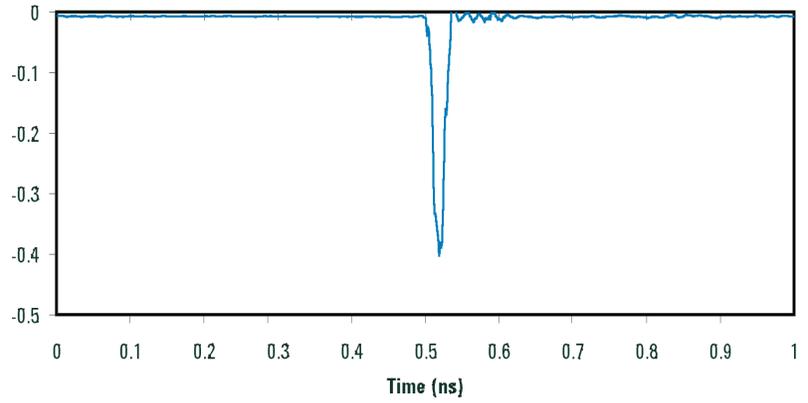


Figure 2. U9391C/F pulse

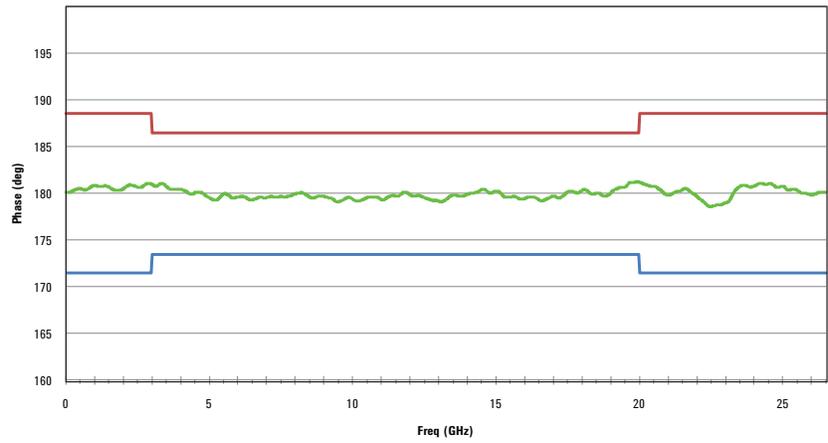


Figure 3. U9391C Comb Generator Phase at 10 MHz PRF

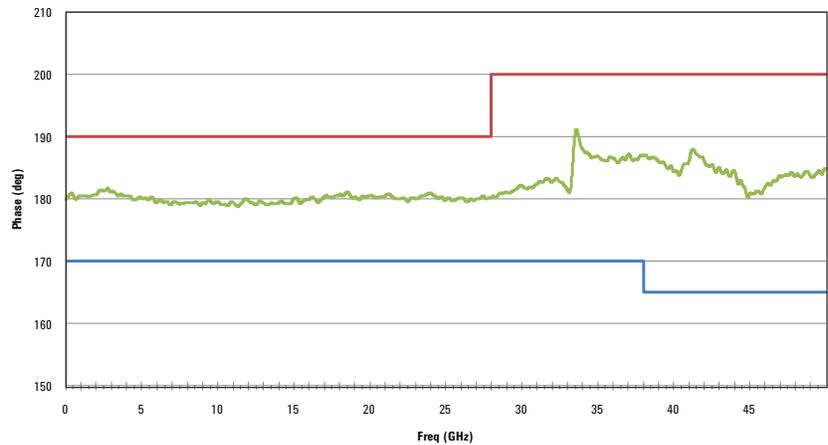


Figure 4. U9391F Comb Generator Phase at 10 MHz PRF

Typical Performance

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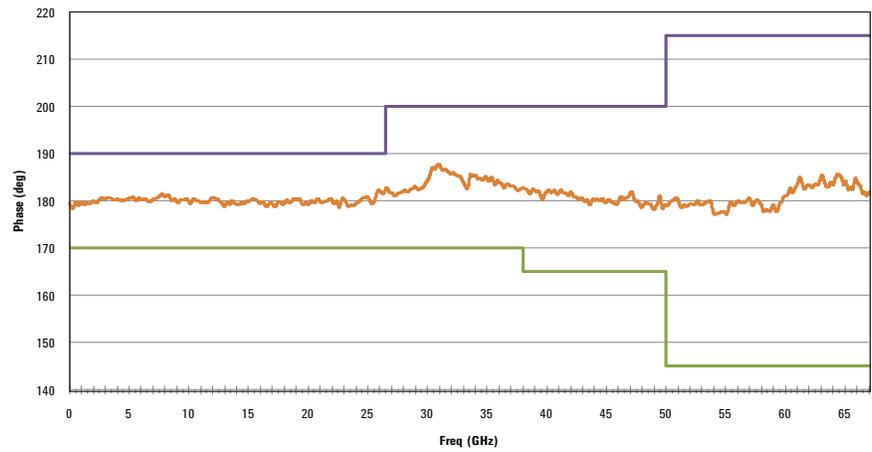


Figure 5. U9391G Comb Generator Phase at 10 MHz PRF

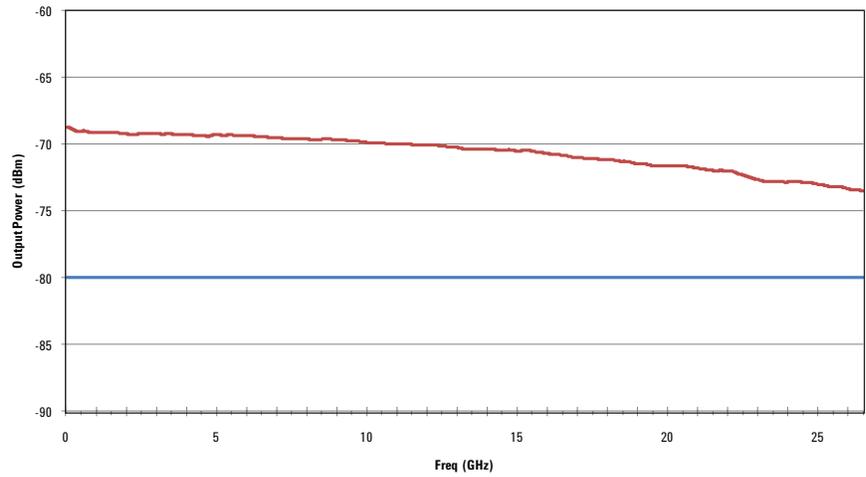


Figure 6. U9391C Comb Generator Output Power at 10 MHz PRF

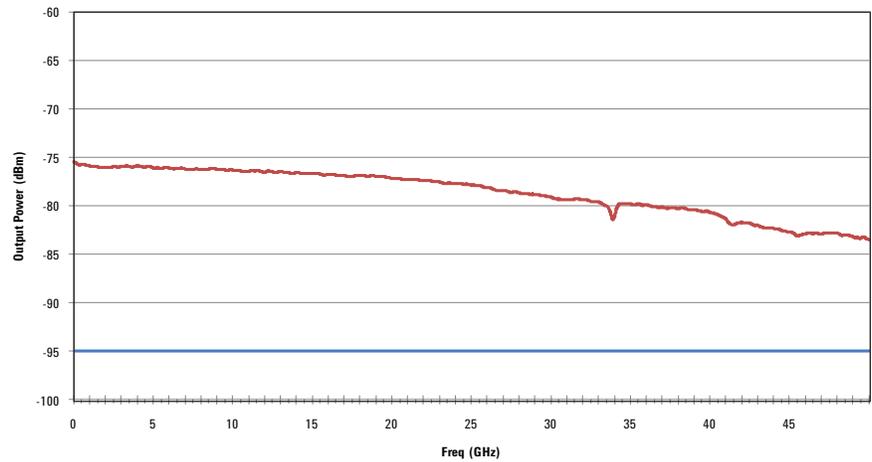


Figure 7. U9391F Comb Generator Output Power at 10 MHz PRF

Typical Performance

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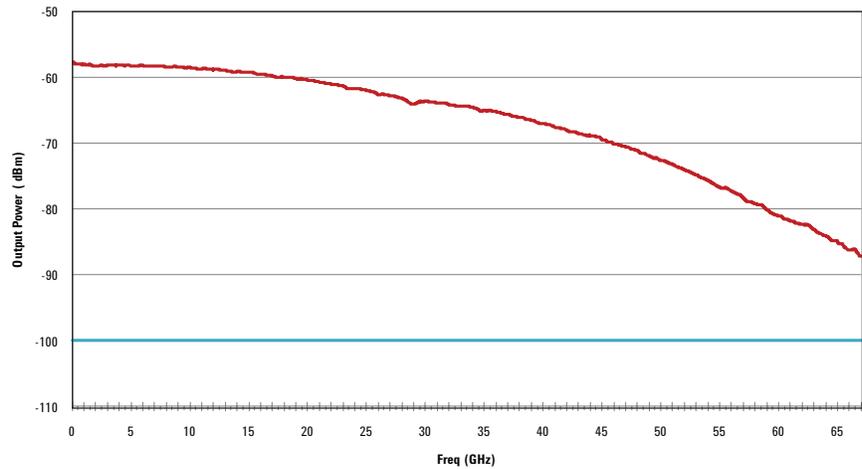


Figure 8. U9391G Comb Generator Output Power at 10 MHz PRF

Ordering Information

Product

U9391C 26.5 GHz Comb Generator¹

U9391F 50 GHz Comb Generator¹

U9391G 67 GHz Comb Generator¹

Connector options

There are two connector options available for the Keysight U9391C/F/G comb generator.

- Option FFF - female (output connector)
- Option FFM - male (output connector)

U9391-60009 squaring circuit is available for the U9391F and U9391G only.

Warranty, calibration and services

- Option 1A7 ISO 17025 compliant calibration
- Option A6J ANSI Z540 compliant calibration

1. U9391C/F/G comb generators are devices (patented design) designed as a phase reference standard for N5242A/N5245A/N5247A PNA-X network analyzers. PNA-X Options 400, 419, 080, 510 are required. www.keysight.com/find/pnax

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