Vector Signal Generator
Model AP5041A and AP5042A

Single- and Multi-Channel Performance Generators
100 kHz to 40 GHz

KEYSIGHT

Table of Contents

Definitions and Conditions

Specifications represent warranted performance of a calibrated instrument that has been stored for a minimum of 2 hours within the operating temperature 23 °C, unless otherwise stated, and after a 45-minute warm-up period. The specifications include measurement uncertainty. Data represented in this document are specifications unless otherwise noted.

Nominal (nom) values indicate the expected mean or average performance, or an attribute whose performance is by design, such as the 50-ohm connector. This data is not warranted and is measured at room temperature (approximately 23 °C).

Measured (meas) describes an attribute measured during the design phase for purposes of communicating expected performance, such as amplitude drift vs. time. This data is not warranted and is measured at room temperature (approximately 23 °C).

Channels

Model	Channel Count
AP5041A	1
AP5042A	1, 2, 3 or 4 independent and phase coherent

Frequency

Frequency Option	CW Frequency Range	Settable CW Frequency Range	RF Output Connector (AP5041A)	RF Output Connector (AP5042A)
504	100 kHz to 4 GHz	100 kHz to 4.15 GHz	Type-N (f)	SMA (f)
506	100 kHz to 6 GHz	100 kHz to 6.6 GHz	Type-N (f)	SMA (f)
512	100 kHz to 12 GHz	100 kHz to 12 GHz	Type-N (f)	SMA (f)
520	100 kHz to 20 GHz	100 kHz to 20 GHz	2.92 mm (m)	SMA (f)
540	100 kHz to 40 GHz	100 kHz to 43.5 GHz	2.92 mm (m)	2.92 mm (f)

Frequency Resolution

CW	0.001 Hz

Phase Adjustment

Phase offset range	0° to 360°
Phase offset resolution	0.01°

Frequency Switching Modes

F1	Normal mode (random phase)
F2	Phase coherent switching (Opt. PHS): Between ≥ 2 AP504xA units using Option SNC or between channels in one AP5042A
F3	Phase calibratable mode (Opt. PCM) (supported to 20 GHz only)

Frequency Reference

Frequency Accuracy		Option LN1	Option LN2
Initial accuracy (nom)	± 10 ppb		
Aging rate (nom) [1]	First year	<± 500 ppb	<± 20 ppb
	Per day	<± 5 ppb	<± 0.5 ppb
Temperature effects (nom)	Full temperature range	<± 100 ppb	<± 20 ppb

External Reference Input

Mode	Phase lock to external reference
Frequency	10 MHz
Input power (nom)	-5 dBm to +10 dBm
Impedance (nom)	50 Ω
Lock range (nom)	± 1.5 ppm ± 0.3 ppm (Opt. LN2)
Connector	BNC (f)

Flexible Reference Input (Option 1ER)

Mode	Phase lock to external reference (Opt. LN2 disabled)
Frequency	5 MHz to 250 MHz
Frequency resolution	1 MHz
Input power (nom)	-5 dBm to +10 dBm
Impedance (nom)	50 Ω
Lock range (nom)	± 1.5 ppm

Reference Output

Frequency	10 MHz, 100 MHz
Power (measured)	> 0 dBm, 50 Ω load
Connector	BNC (f)

[1] After 30 days of continuous operation

High Performance Reference Input (Option SNC)

Mode	Bypass of internal reference
Frequency	6 GHz
Input power (nom)	0 dBm to +10 dBm
Impedance (nom)	50 Ω
Connector	SMA (f)

High Performance Reference Output (Option SNC)

Frequency	6 GHz
Power (measured)	> 3 dBm, 50 Ω load
Connector	SMA (f)

Sweep Mode (Frequency and Power)

Operating mode	Linear step sweep (equally spaced frequency or amplitude)
Amplitude range	A3 (ALC OFF (agile mode))
Sweep shape	Sawtooth
Dwell time settable	500 µs to 30 s 8 ns to 30 s (opt. UNZ)
Delay time settable	200 ns to 30s 8 ns to 30s (opt. UNZ)
Dwell/delay time resolution	8 ns
Number of points:	2 to 9,999 (SCPI: 2 to 2^{32} -1)
Sweep count:	Infinite or 1 to 9,999 (SCPI: 1 to 2^{32} -1)
Triggering	See “Trigger” section of datasheet
Trigger type	Continuous (full sweep)
Continuous Mode	Free run, trigger and run

Power

Output Parameters

Leveling modes	A1 – ALC ON and hold ON A2 – ALC OFF A3 – ALC OFF (agile mode)	Leveling on parameter change or on command, active modulations will be interrupted
Resolution (nom)	0.01 dB (A1, A2) 0.5 dB (A3)	
Attenuator Type	Opt. 1E2 for 504 Opt. 2E2 for 506, 512, 520 Opt. 1EH for 506, 512, 520 Opt. 3E2 for 540	Electronic
	Opt. 1E1	Mechanical
Output impedance (nom)	50 Ω	
Maximum reverse power (nom)	0.5 W, 5 VDC	

Settable Range

Levelling Mode	Standard	Opt. 1E2	Opt. 2E2	Opt. 1EH	Opt. 3E2	Opt. 1E1
A1, A2	-20 to +25 dBm	-55 to +25 dBm	-80 to +25 dBm	-80 to +25 dBm	-80 to +25 dBm	-135 to +25 dBm
A3	-20 to + 15 dBm	-55 to +15 dBm	-80 to +15 dBm	-80 to +15 dBm	-80 to +15 dBm	-20 to +15 dBm

Maximum Output Power in CW, A1, A2 Mode (Measured), (Option 504)

Frequency Range	Standard	UNZ	1E1	1E2	1E2 + UNZ
100 kHz to 10 MHz	+8 dBm	+8 dBm	+8 dBm	+8 dBm	+8 dBm
> 10 MHz to 100 MHz	+17 dBm	+17 dBm	+17 dBm	+15 dBm	+15 dBm
> 100 MHz to 2.2 GHz	+22 dBm	+23 dBm	+21 dBm	+20 dBm	+21 dBm
> 2.2 GHz to 4 GHz	+20 dBm	+23 dBm	+19 dBm	+17 dBm	+20 dBm

Maximum Output Power in CW, A1, A2 Mode (Measured) (Option 520)

Frequency Range	Standard
100 kHz to 10 MHz	+10 dBm
> 10 MHz to 50 MHz	+17 dBm
> 50 MHz to 200 MHz	+20 dBm
> 200 MHz to 2.2 GHz	+23 dBm
> 2.2 GHz to 4 GHz	+19 dBm
> 4 GHz to <4.9 GHz	+ 16 dBm
4.9 GHz to 10 GHz	+20 dBm
> 10 GHz to 20 GHz	+16 dBm

Maximum Output Power in CW, A1, A2 Mode (Measured) (Option 540)

Frequency Range	Standard	1E1
100 kHz to 10 MHz	+10 dBm	+10 dBm
> 10 MHz to 50 MHz	+17 dBm	+17 dBm
> 50 MHz to 200 MHz	+20 dBm	+ 20 dBm
> 200 MHz to 2.2 GHz	+23 dBm	+23 dBm
> 2.2 GHz to 4 GHz	+19 dBm	+19 dBm
> 4 GHz to <4.9 GHz	+16 dBm	+16 dBm
4.9 GHz to 11 GHz	+22 dBm	+20 dBm
> 11 GHz to 20 GHz	+20 dBm	+19 dBm
20 GHz to 27 GHz	+18 dBm	+16.5 dBm
27 GHz to 31 GHz	+15 dBm	+12 dBm
31 GHz to 38 GHz	+16 dBm	+13.5 dBm
38 GHz to 40 GHz	+15 dBm	+11 dBm

Absolute Level Accuracy in CW, A1, (Measured) (Option 504)

Frequency Range	+15 dBm to -20 dBm	Option 1E2: -20 dBm to -55 dBm	Option 1E1: -20 dBm to -65 dBm	Option 1E1: -65 dBm to -120 dBm
100 kHz to 300 kHz	±3.0 dB	±3.0 dB	±3.0 dB	±3.0 dB
> 300 kHz to 20 MHz	±1.5 dB	±1.5 dB	±1.5 dB	±3.0 dB
> 20 MHz to 4 GHz	±0.3 dB	±0.8 dB	±0.4 dB	±1.0dB

Absolute Level Accuracy in CW, A1, (Measured) (Option 520)

Frequency Range	Standard +15 dBm to -20 dBm
100 kHz to 3 MHz	±1.5 dB
> 3 MHz to 10 MHz	±0.8 dB
> 10 MHz to 200 MHz	±0.4 dB
> 200 MHz to 4 GHz	±0.2 dB
> 4 GHz to 20 GHz	±0.4 dB

Absolute Level Accuracy In CW, A1, (Measured) (Option 540)

Frequency Range	Standard +15 dBm to -20 dBm
100 kHz to 3 MHz	±1.5 dB
> 3 MHz to 10 MHz	±0.8 dB
> 10 MHz to 200 MHz	±0.4 dB
> 200 MHz to 4 GHz	±0.2 dB
> 4 GHz to 21 GHz	±0.4 dB
> 21 GHz to 40 GHz	±0.5 dB

Absolute Level Accuracy in CW, A3, (Measured) (Option 504)

Frequency Range	+15 dBm to -20 dBm	Option 1E2: -20 dBm to -55 dBm	Option 1E1: -20 dBm to -65 dBm	Option 1E1: -65 dBm to -120 dBm
100 kHz to 300 kHz	±3.0 dB	±3.0 dB	±3.0 dB	±3.0 dB
> 300 kHz to 20 MHz	±1.5 dB	±1.5 dB	±1.5 dB	±3.0 dB
> 20 MHz to 4 GHz	±0.8 dB	±1.2 dB	±0.8 dB	±1.2 dB

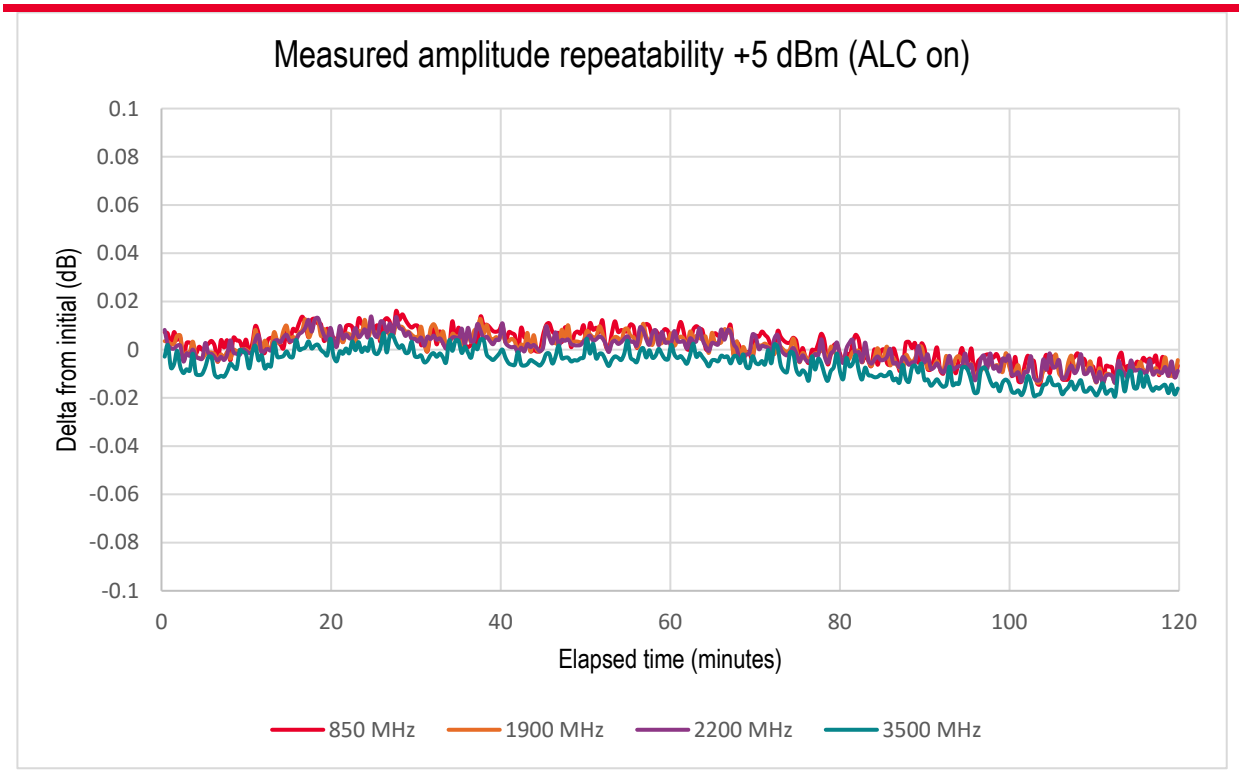
Absolute Level Accuracy in CW, A3, (Measured) (Option 520)

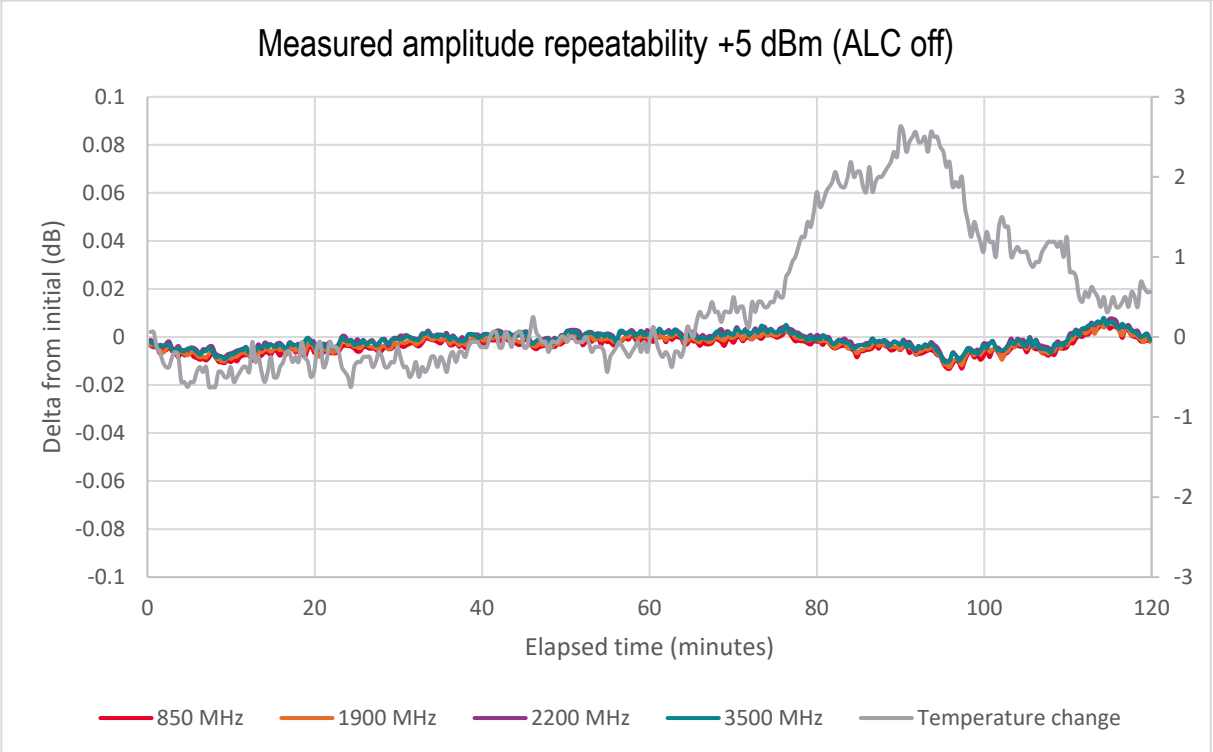
Frequency Range	Standard +15 dBm to -20 dBm
100 kHz to 100 MHz	±1.0 dB
> 100 MHz to < 4.9 GHz	±0.5 dB
4.9 GHz to 20 GHz	±0.9 dB

Absolute Level Accuracy in CW, A3, (Measured) (Option 540)

Frequency Range	Standard +15 dBm to -20 dBm
100 kHz to 100 MHz	±1.0 dB
> 100 MHz to < 4.9 GHz	±0.5 dB
4.9 GHz to 27 GHz	±0.9 dB
> 27 GHz to 40 GHz	±2.0 dB

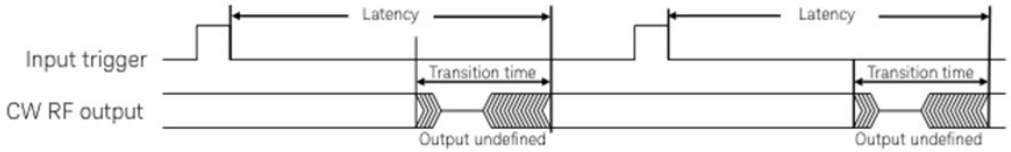
Amplitude Repeatability, +5 dBm (Option 504)





Repeatability measures the ability of the instrument to return a given power setting after a random excursion to any other frequency and power setting. It should not be confused with absolute level accuracy.

Switching Speed



Latency and RF Transition Time for Frequency Changes (F1-F3) and Amplitude Changes (A1, A2) (Measured)[2]

CW operation	< 10 ms
I/Q modulation active	< 10 ms

RF Transition Time for Frequency Changes (F1-F3) and Amplitude Changes (A3) (Measured)[3]

Configuration	Opt. 504	Opt. 506, 512, 520	Opt. 540
Standard (no attenuator option)	2.0 µs	2.3 µs	5.1 µs
Opt. 1E2, 2E2, 3E2	2.0 µs	2.7 µs	5.3 µs
Opt. PHS (no attenuator option)	2.5 µs	3.5 µs	5.9 µs
Opt. 1E2, 2E2, 3E2 and Opt. PHS	3.0 µs	3.9 µs	6.2 µs

Latency for Frequency Changes (F1-F3) and Amplitude Changes (A3) (Measured)[4]

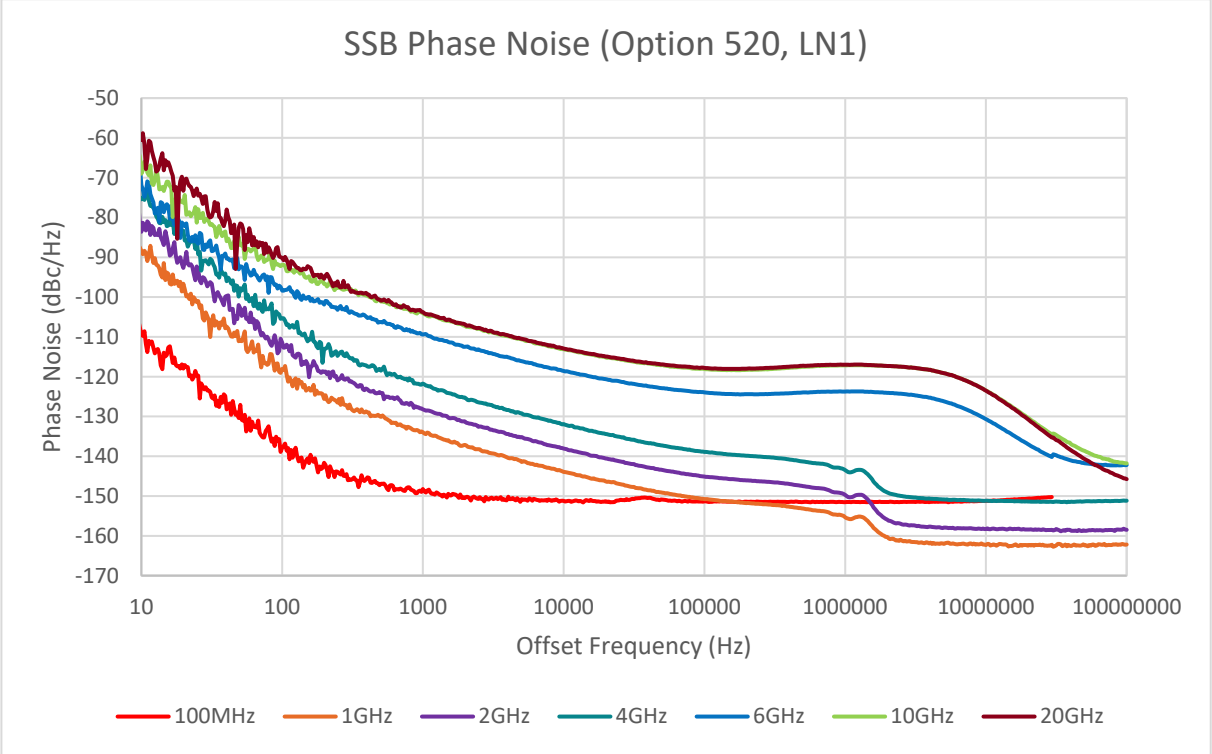
Configuration	Opt. 504	Opt. 506, 512, 520	Opt. 540
Standard	0.5 ms	0.5 ms	0.5 ms
Opt. UNZ	2.6 µs	3.1 µs	5.9 µs
Opt. UNZ and Opt. 1E2 / 2E2 / 3E / 1EH	3.0 µs	3.9 µs	6.5 µs
Opt. UNZ and Opt. PHS	3.5 µs	4.7 µs	7.1 µs
Opt. UNZ and Opt. 1E2 / 2E2 / 3E2 / 1EH and Opt. PHS	4.0 µs	5.1 µs	7.4 µs

2 Defined from receipt of SCPI command to next valid RF signal (phase settled to 0.2 rad, amplitude within 1dB of final value).
3 Defined from valid RF signal to next valid RF signal (phase settled to 0.2 rad, amplitude within 1dB of final value). The RF signal will be blanked during transition.
4 Defined from received trigger command to RF invalid.

Phase Noise

Absolute SSB Phase Noise (CW) at +10 dBm or Maximum Output Power in dBc/Hz, (Measured) (Option LN1), [ ] = Option LN2

Frequency	10 Hz	100 Hz	1 kHz	10 kHz	100 kHz	1 MHz	10 MHz	100 MHz
100 MHz	-110 [-120]	-136 [-133]	-148	-150	-151	-151	-151	-
1 GHz	-89 [-102]	-117 [-112]	-133	-142	-150	-155	-162	-162
2 GHz	-83 [-96]	-111 [-106]	-127	-136	-144	-150	-158	-158
4 GHz	-76 [-90]	-105 [-99]	-121	-130	-138	-143	-151	-151
6 GHz	-72 [-80]	-98 [-91]	-109	-119	-124	-123	-130	-142
10 GHz	-67 [-76]	-92 [-89]	-103	-113	-118	-116	-124	-142
20 GHz	-60 [-74]	-85 [-85]	-103	-113	-118	-116	-124	-146
40 GHz	-54 [-69]	-80 [80]	-103	-113	-118	-116	-124	-146



Absolute SSB Phase Noise (CW) at +10 dBm or Maximum Output Power in dBc/Hz, (Measured) (Option LN1 + UNZ), [ ] = Option LN2 + UNZ

Frequency	10 Hz	100 Hz	1 kHz	10 kHz	100 kHz	1 MHz	10 MHz	100 MHz
100 MHz	-110 [-120]	-136 [-133]	-148	-150	-151	-151	-151	-
1 GHz	-89 [-102]	-117 [-112]	-133	-142	-150	-155	-162	-162
2 GHz	-83 [-96]	-111 [-106]	-127	-136	-144	-150	-158	-158
4 GHz	-76 [-90]	-105 [-99]	-121	-130	-138	-143	-151	-151
6 GHz	-72 [-80]	-98 [-91]	-109	-119	-124	-118	-116	-142
10 GHz	-67 [-76]	-92 [-89]	-103	-113	-118	-116	-117	-142
20 GHz	-60 [-74]	-85 [-85]	-103	-113	-118	-116	-117	-146
40 GHz	-54 [-69]	-80 [80]	-103	-113	-118	-116	-117	-146

Spectral Purity

Harmonics (CW), at 0 dBm, () = Measured (Option 504)

Frequency Range	Standard	UNZ
100 kHz to 2 MHz	< -20 dBc	< -20 dBc
> 2 MHz to 4 GHz	< -41 dBc (-45 dBc)	< -38 dBc (-42 dBc)

Harmonics (CW), at 0 dBm, Measured (Option 520)

Frequency Range	Standard
100 kHz to 2 MHz	< -20 dBc
> 2 MHz to <4.9 GHz	< -42 dBc
4.9 GHz to 12 GHz	< -30 dBc
> 12 GHz to 17 GHz	< -65 dBc
>17 GHz to 20 GHz	< -60 dBc

Harmonics (CW), at 0 dBm, Measured (Option 540)

Frequency Range	Standard
100 kHz to 300 kHz	< -30 dBc
> 300 kHz to <4.9 GHz	< -43 dBc
> 4.9 GHz to 7.5 GHz	< -32 dBc
> 7.5 GHz to 12 GHz	< -35 dBc
> 12 GHz to 17 GHz	< -30 dBc
> 17 GHz to 25 GHz	< -27 dBc

Non-Harmonics (CW), at 0 dBm, Measured, (Option 504)

Frequency Range	Standard	Option UNZ
> 100 kHz to 4 GHz	< -60 dBc	< -55 dBc

Non-Harmonics (CW), at 0 dBm, Measured, (Option 520)

Frequency Range	Standard
> 100 kHz to 6 GHz	< -60 dBc
> 6 GHz to 8.5 GHz	< -57 dBc
> 8.5 GHz to 15 GHz	< -50 dBc
> 15 GHz to 17 GHz	< -60 dBc
> 17 GHz to 20 GHz	< -48 dBc

Non-Harmonics (CW), at 0 dBm, Measured, (Option 540)

Frequency Range	Standard
> 100 kHz to 7 GHz	<- 60 dBc
> 7 GHz to 12 GHz	< -50 dBc
> 12 GHz to 16 GHz	< -60 dBc
> 17.8 GHz to 17.9 GHz	< -45 dBc
> 17.9 GHz to 31.6 GHz	< -60 dBc
> 31.6 GHz to 32.7 GHz	< -39 dBc
> 32.7 GHz to 40 GHz	< -50 dBc

Subharmonics (CW), Measured

None

Pulse Modulation (Option PMR)

Pulse Modulation

	I/Q (Base Band) Modulator	RF Modulator
On/off ratio (meas)	90 dB	40 dB
Rise/fall times (meas)	5 ns	5 ns
Video feed-through (meas) at PRF=500 kHz, 0 dBm 50% duty cycle	-70 dB at 1 GHz -50 dB at 20 GHz	-
RF delay to video (meas)	400 to 1000 ns	10 ns
Pulse overshoot (meas)	± 1 dB	± 1 dB
External pulse jitter (nom)	± 8ns	± 10 ps
External pulse delay (meas)	< 1 us	20 ns
External pulse input	MF1 IN, MF2 IN	

Internal Pulse Generator

Pulse period	16 ns to 10 s
Pulse width	8 ns to 10 s
Resolution	8 ns
Triggering	See “Trigger” section of datasheet
Trigger type	Continuous (full sweep)
Continuous mode	Free run, trigger and run

Pulse Descriptor Words (Option PDW)[5]

The PDW option enables agile control of frequency, amplitude, phase, time, and waveform inside the instantaneous bandwidth. Each PDW will address an I/Q waveform segment or create the I/Q waveform in real time, including pulse modulation.

This feature can only be configured over SCPI or the PC software.

PDW		
Amplitude operation	A3 (ALC OFF (agile mode))	
Upload methods	Individual SCPI commands, SCPI block data (.csv through PC software)	
Pulse width, start time range	96 ns to 208 days	8 ns to 208 days with opt. UNZ
Pulse width, start time resolution	8 ns	
Pulse execution rate	Up to 498 k pulses/s, depends on configuration of the device, see table “RF transition time for frequency changes (F1-F3) and amplitude changes (A3)” + pulse width	
PDW time mode	Absolute, relative	
PDW parameters	Start time, pulse width, frequency, power, phase, waveform segment[6], 8bit marker	
Intra-pulse modulation	(pulsed) Linear phase sweep	
Phase sweep step time	8 ns to 4.29 s	

PDW List Mode	
The list mode plays a predefined list of PDWs located in and read from the instrument’s FPGA memory.	
Number of PDWs	1 to 1024 1 to 60 M with limited pulse execution rate of 166 k pulses/s (using SCPI if > 1M PDW)
List repetition	Infinite or 1 to 65 k
List triggering	See “Trigger” section of datasheet
Trigger type	Continuous
Continuous modes	Free run, trigger and run

PDW Streaming Mode Over FCP Interface (Requires Option FCP)	
Streaming provides agile control of PDW parameters via a continuous stream of PDWs transferred from Fast Control Port (Option FCP). Each PDW consists of up to 255 Bytes. The streaming PDWs are queued in a buffer and scheduled for synchronous execution based on the time stamp information contained in each PDW.	
FCP interface rate	> Pulse execution rate
FCP sample rate	250 MHz
FCP data format	Address (8 bits), data (8 bits), valid signal
PDW streaming buffer size	1024
PDW streaming trigger	none

5 Keysight has self-classified AP504xA option PDW as subject to ITAR export control when in the United States and therefore notifying the customer that the items should be treated as ITAR once received into the United States.

6 I/Q-modulator sample rate fixed at 500 MHz

Vector Modulation

Internal I/Q Baseband Generator Adjustments

Internal I/Q adjustments	None
Internal real-time complex digital I/Q filters	None

Carrier Leakage

None (digital I/Q modulation)

Frequency Response Over Full Modulation Bandwidth, Measured, (Option 504)

Frequency Range	Standard	UNZ	1E1	1E2	1E2 + UNZ
300 MHz to 4 GHz	± 1.4 dB / ± 7°	± 0.9 dB / ± 7°	± 1.4dB / ± 8°	± 1.6 dB / ± 8°	± 1.4 dB /± 12°

Frequency Response Over Full Modulation Bandwidth, Measured, (Option 520)

Frequency Range	Standard
1 GHz to 4 GHz	± 1.2 dB / ± 8°
4 GHz to 8.5 GHz	± 1.5 dB / ± 10°
8.5 GHz to 12 GHz	± 3.2 dB / ± 12°
12 GHz to 20 GHz	± 3.2 dB / ± 10°

Frequency Response Over Full Modulation Bandwidth, Measured, (Option 540)

Frequency Range	Standard
1 GHz to 4 GHz	± 1.2 dB / ± 8°
> 4.9 GHz to 16.5 GHz	± 2.4 dB / ± 14°
> 16.5 GHz to 23 GHz	± 3.8 dB / ± 18°
> 23 GHz to 28 GHz	± 2.4 dB / ± 13°
> 28 GHz to 35 GHz	± 3.6 dB / ± 22°
> 35 GHz to 40 GHz	± 2.4 dB / ± 15°

Frequency Response Over ±50 Mhz Modulation Bandwidth, Measured, (Option 540)

Frequency Range	Standard
> 4 GHz to 20 GHz	± 1.0 dB / ± 5°
> 20 GHz to 40 GHz	± 2.0 dB / ± 12°

Internal Baseband Generator

This feature can only be configured over SCPI and the PC software AP504xA VSG GUI, except for options: UNT, 403.

Internal Baseband Generator

I/Q file resolution	16 bits
Waveform granularity	1 sample
Frequency offset	± half maximum bandwidth
Sample rate resolution	1 Hz
Maximum RF (I + Q) bandwidth (nom)	400 MHz
Sample rate	1 Hz to 500 MHz

Arbitrary Waveform Memory

Maximum arbitrary waveform playback memory	Without marker	512 MSa
	With marker signals active	334 MSa

Waveform Transfer Rates, No Markers, Unencrypted (Meas)

GUI to base band generator (LAN)	50 Mbit/s or 1.5 MSa/s

Waveform Segments

Segment length minimum[7]	96 246, with markers signals active
Segment length maximum	See Maximum arbitrary waveform playback memory
Segment length quantum	See Waveform granularity
Maximum number of segments	8192
Segment changeover mode	Seamless, immediate
Switching speed (meas)[8]	2 µs

Waveform Sequences

Maximum number of sequences	1
Maximum number of segments per sequences[9]	2048
Maximum number of repetitions	10 M

7 Shorter Waveforms will be automatically extended by cyclically repeating the waveform.
8 Waveforms are pre-loaded, at 500 MHz sample rate, immediate segment changeover with Opt. FCP interface.
9 All uploaded segments must have the same playback rate and the same marker configuration.

Waveform Triggers

Type	Continuous
Continuous modes	Free run, trigger and run
Other parameters	See “Trigger” section of datasheet

Markers[10]

Number of markers	4	
Marker (nom)	Sample rate ≤ 125 MHz	Sample rate > 125 MHz
Duration minimum value	1 sample	4 samples
Maximum duration variation	± 1 sample	± 8 ns
Maximum additional jitter	± 1 sample	± 8 ns

AWGN (Option 403)

Type	Real-time
Modes of operation	Standalone or digitally added to the arbitrary waveform
Distribution density	Gaussian, statistical, $\mu = 0$, $\sigma^2 = 1$ (separate for I and Q)
Crest factor (nom)	≤ 21 dB
Periodicity	> 1×10^{40} hours
Carrier-to-noise ratio (nom)	-60 dB to +90 dB
Carrier-to-noise ratio resolution (nom)	0.01 dB
Carrier-to-noise ratio formats	C/N
Noise bandwidth	Standalone: See sample rate specification of the baseband generator Digitally added: 0.8 of the actual set baseband generator sample rate

10 Markers are defined during the waveform generation process and cannot be modified afterwards.

I/Q Based Analog Modulation (Opt. UNT)

Amplitude Modulation	
Waveform	Sine
AM-rate	0.1 Hz to 100 MHz
AM depth	0 to 100 %
Frequency Modulation	
Waveform	Sine
FM-rate	0.1 Hz to 100 MHz
FM deviation	0 Hz to 200 MHz (peak)
Phase Modulation	
Waveform	Sine
ΦM-rate	0.1 Hz to 100 MHz
ΦM deviation	0 to 100 rad

Simultaneous Modulation

	AM	FM	ΦM	Pulse	Waveform I/Q	AWGN
AM	+	-	-	+	-	+
FM	-	+	-	+	-	+
ΦM	-	-	+	+	-	+
Pulse	+	+	+	+	+	+
Arbitrary I/Q	-	-	+	+	+	+
AWGN	+	+	+	+	+	+

+ = compatible **– = incompatible**

Avionics Modulation (AP5041A only, Option 302)

Avionics Modulation, () = Measured

DME	
Operating modes	Interrogation & reply
DME channel	X, Y
Frequency range	960 MHz to 1215 MHz
Pulse pattern repetition rate / - resolution / accuracy	10 Hz to 5 kHz / 0.1 Hz / ± 0.1 Hz
Pulse-to-pulse level range / - accuracy	-80 dB to 80 dB / ≤ ± 0.2 dB (± 0.1 dB)
Main pulse width / - resolution / -accuracy (up to 4 additional pulses / pairs)	100 ns to 100 µs / 0.1 ns / ≤ ± 17 ns (± 1 ns)
Main pulse rise/fall time / - resolution / - accuracy	100 ns to 100 µs / 0.1 ns / ≤ ± 7 ns
Main pulse pair spacing / - resolution / - accuracy	100 ns to 100 µs / 0.1 ns / ≤ ± 17 ns
Echo pulse pair delay / - resolution / - accuracy	2 µs to 8 µs / 0.1 ns / ≤ ±17 ns
Echo pulse pair attenuation range / - resolution / - accuracy	-3 dB to +12 dB / 0.001 dB / ≤ ±0.2 dB
Interference delay / - resolution / - accuracy	1 µs to 8 µs / 0.1 ns / ≤ ± 17 ns
Interference attenuation range / - resolution / - accuracy	0 dB to 30 dB / 0.001 dB / ≤ ± 0.2 dB
Receiver dead time test pulse pair delay / - resolution / - accuracy	10 µs to 100 µs / 0.1 ns / ≤ ± 17 ns
Identification code transmission	3-character code: Repetition period, morse dot length
VOR	
Carrier frequency range	108 MHz to 118 MHz
Bearing direction	From / to
Bearing range / - resolution / - accuracy	0 to 360° / 0.001° / ± 1°
AM0 component (30 Hz navigation variable signal) Depth range / - resolution / - accuracy	0 to 50% / 0.01% / ± 0.5%
AM0 distortion (THD)	≤ 2%
AM1 component (9'960 Hz navigation reference subcarrier) Depth range / - resolution / - accuracy	0 to 50% / 0.01% / ± 0.5% (± 0.3%)
AM1 component frequency range / - resolution / - accuracy	5 kHz to 15 kHz / 0.1 Hz / ± 0.1 mHz
AM1 distortion (THD)	≤ 2%
FM component (30 Hz navigation reference signal) Index / - resolution / - accuracy	0 to 33.3 / 0.01 / (± 0.033)
FM component deviation accuracy, 480 Hz deviation	± 1 Hz (± 0.5Hz)
Identification code component (4 characters code) AM frequency range / - resolution / - accuracy	300 Hz to 1.74 kHz / 0.1 Hz / ± 0.1 mHz
Identification code component AM depths range / - resolution / - accuracy	0 to 50% / 0.01% / ± 0.5% (± 0.3%)

Avionics Modulation, () = Measured

ILS: Localizer (LOC)		
Carrier frequency range		108 MHz to 118 MHz
DDM range / - resolution		-20% to 20% / 0.01%
DDM accuracy	at 0 µA DDM	± 1.0 µA (± 0.1 uA) or ± 0.1% (± 0.01%)
	within ±10 µA DDM	± 1.0 µA (± 0.1 uA) or ± 0.1% (± 0.01%)
	within ±150 µA DDM	± 5.0 µA (± 0.1 uA) or ± 0.5% (± 0.01%)
SDM range / - resolution / - accuracy		20% to 60% / 0.01% / ± 1% (± 0.1%)
SDM accuracy, setting 40% RF -30 dBm		1.0%
AM0 component (90 Hz left beam) Depth (change DDSM/SDM) / - resolution / - accuracy		10% to 30% / 0.01% / ± 0.5%
AM0 component frequency range / - resolution / - accuracy		88 Hz to 92 Hz / 0.5 mHz / ± 0.5 mHz
AM1 component (150 Hz right beam) Depth (change DDSM/SDM) / - resolution / - accuracy		10% to 30% / 0.01% / ± 0.5%
AM1 component frequency range / - resolution / - accuracy		147 Hz to 154 Hz / 0.5 mHz / ± 0.5 mHz
AM1 component range to relative phase AM0 component / - resolution / - accuracy		0 to 360° / 0.001° / ± 1° (± 0.1°)
Identification code component (4 characters code) AM frequency / - resolution / - accuracy		300 Hz to 1.74 kHz / 0.5 mHz / ± 0.5 mHz
Identification code component AM depth range / - resolution / - accuracy		0 to 50% / 0.01% / ± 0.5%
ILS: Glide Slope (GS)		
Carrier frequency range		329 MHz to 335 MHz
DDM range / - resolution		-40% to 40% / 0.01%
DDM accuracy	at 0 µA DDM	± 0.8 µA (± 0.1 uA) or ± 0.1% (± 0.012%)
	within ±10 µA DDM	± 0.88 µA (± 0.1 uA) or ± 0.1% (± 0.012%)
	within ±150 µA DDM	± 4.4 µA (± 0.2 uA) or ± 0.5% (± 0.024%)
SDM range / - resolution / - accuracy		40% to 120% / 0.01% / ± 2% (± 0.1%)
SDM accuracy at 80% RF – 30 dBm		± 1%
AM0 component (90 Hz upper beam) Depth (change DDSM/SDM) / - resolution / - accuracy		20% to 60% / 0.01% / ± 0.5%
AM0 component frequency range / - resolution / - accuracy		88 Hz to 92 Hz / 0.5 mHz / ± 0.5 mHz
AM1 component (150 Hz lower beam) Depth (change DDSM/SDM) / - resolution / - accuracy		20% to 60% / 0.01% / ± 0.5%
AM1 component frequency range / - resolution / - accuracy		147 Hz to 154 Hz / 0.5 mHz / ± 0.5 mHz
AM1 component range to relative phase AM0 component / - resolution / - accuracy		0 to 360° / 0.001° / ± 1° (± 0.1°)
Marker Beacon		
AM depth setting range / - resolution		0 to 100% / 0.01%
AM tone accuracy	95% depth	(0.3%)
AM tone distortion	95% depth	(2%)

Trigger

Trigger Input

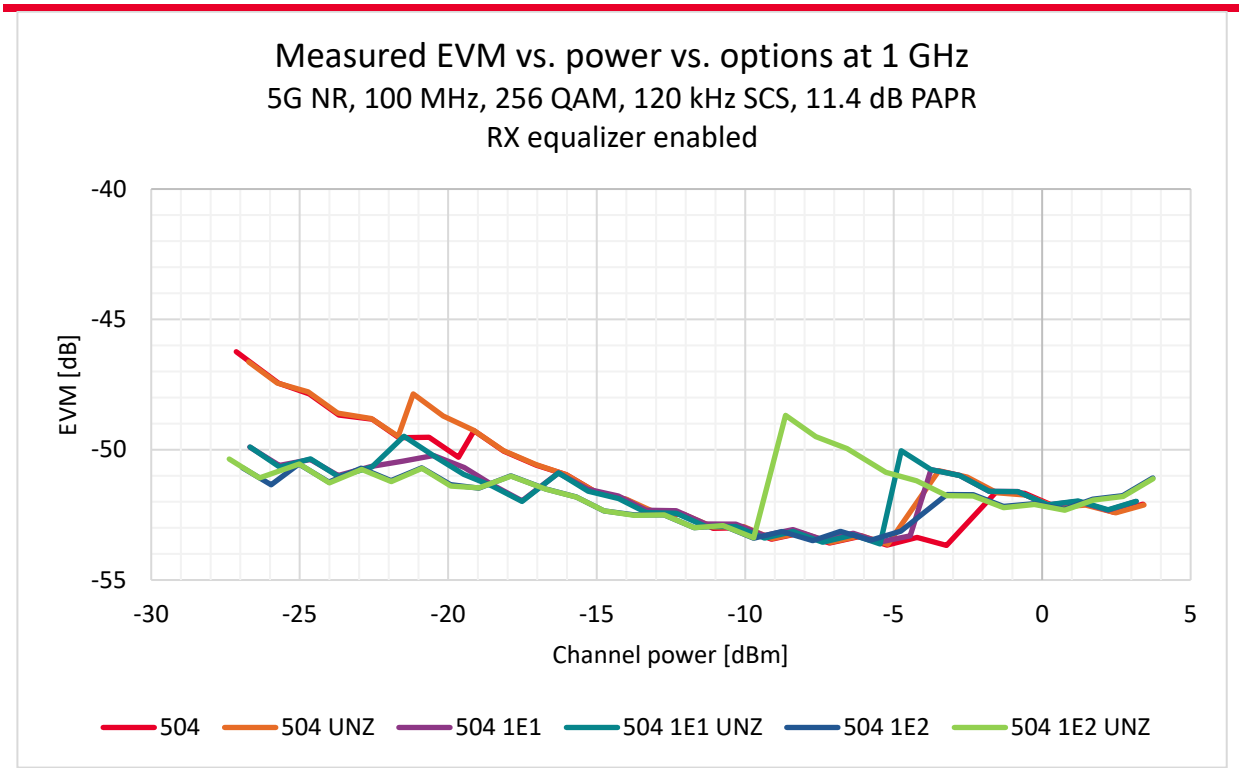
Sources	Immediate, external, bus (GPIB, LAN, USB), global trigger, Synchronous trigger (Opt. SNC)
External input connector	MF1 IN, MF2 IN
External delay time	0 to 8.5 s
External delay resolution	2 ns
Additional external trigger latency (meas)	100 ns
External latency jitter	± 2 ns
External slope	Rising, falling

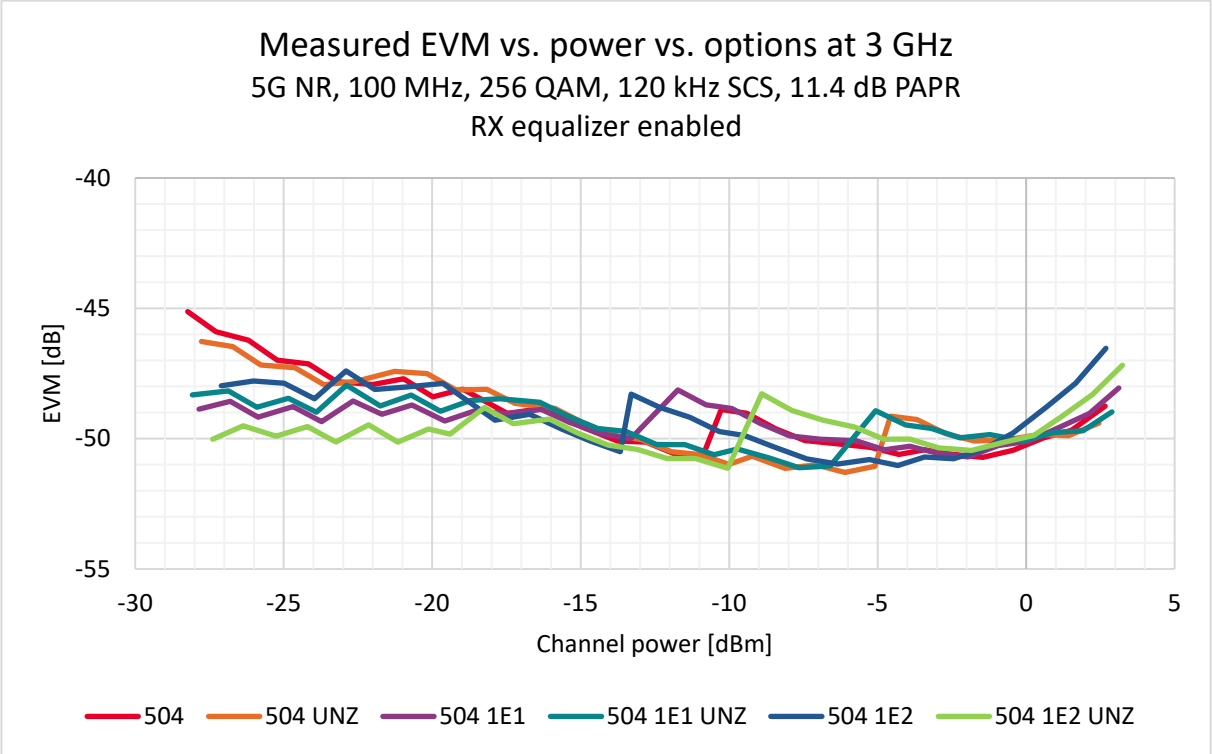
Trigger Output

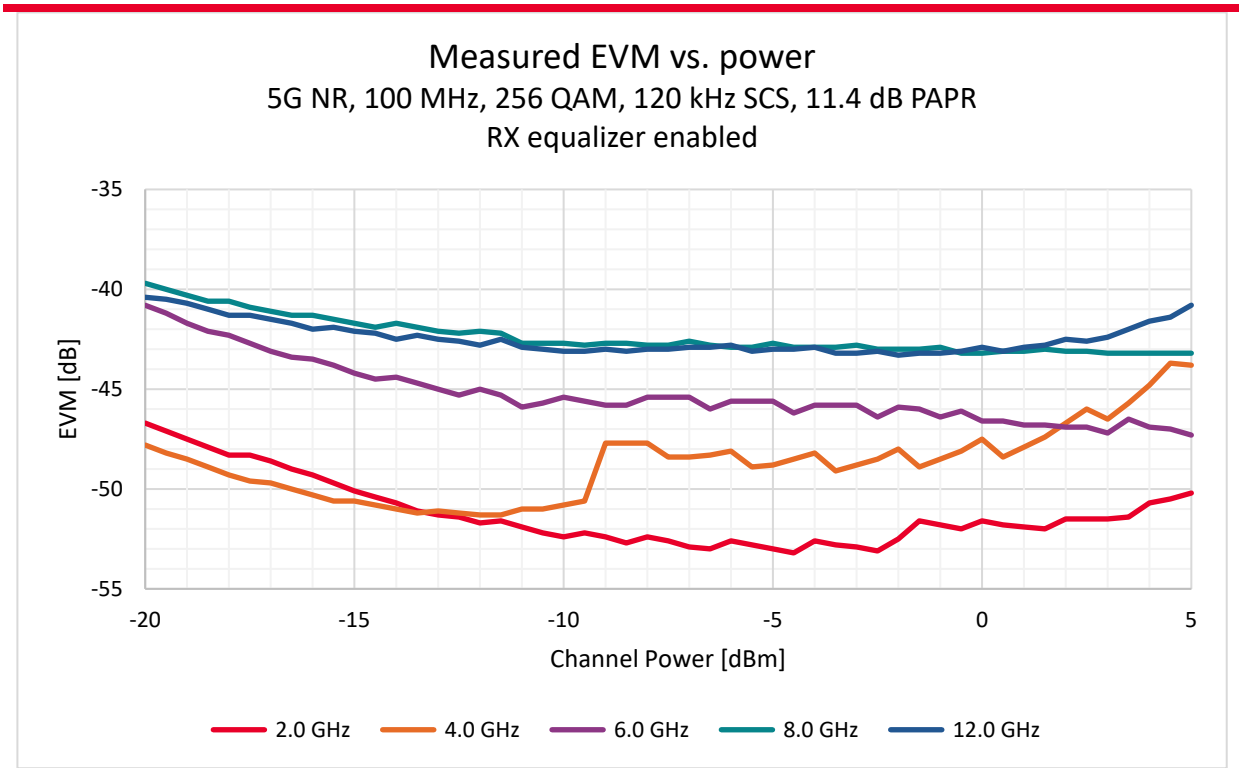
Trigger output connector	MF1 OUT, MF2 OUT
Trigger output polarity	Normal, inverted
Trigger output delay time	0 to 2 µs
Trigger output delay resolution	2 ns
Trigger output pulse width	8 ns to 16 µs
Trigger output pulse width resolution	8 ns

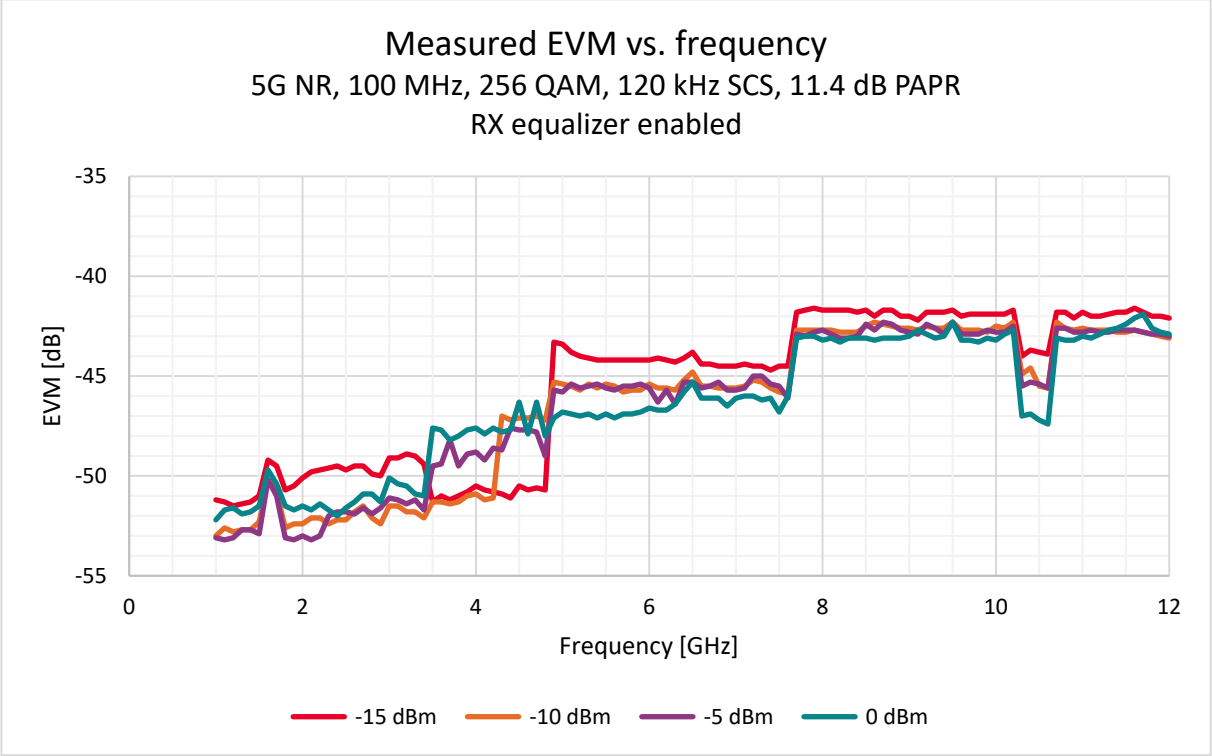
Error Vector Magnitude (EVM)

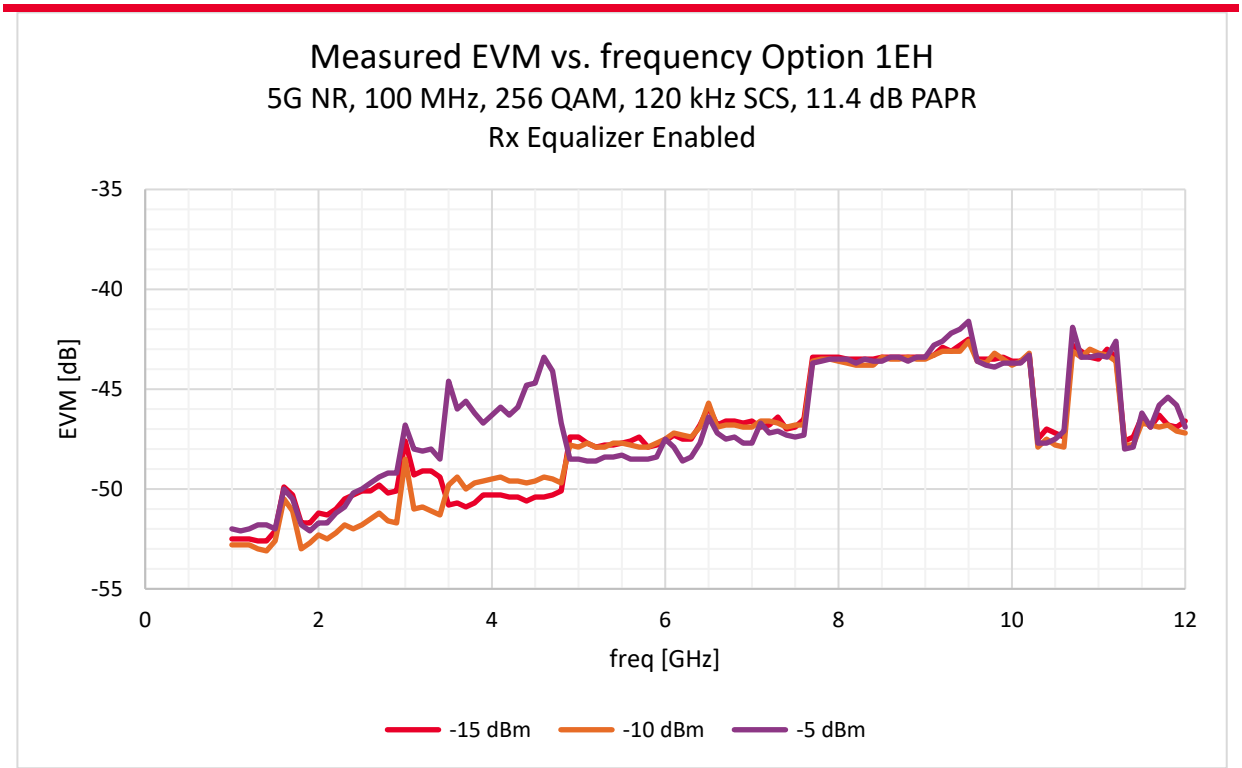
EVM for 5G NR 100 MHz Bandwidth, Measured (Option 504)

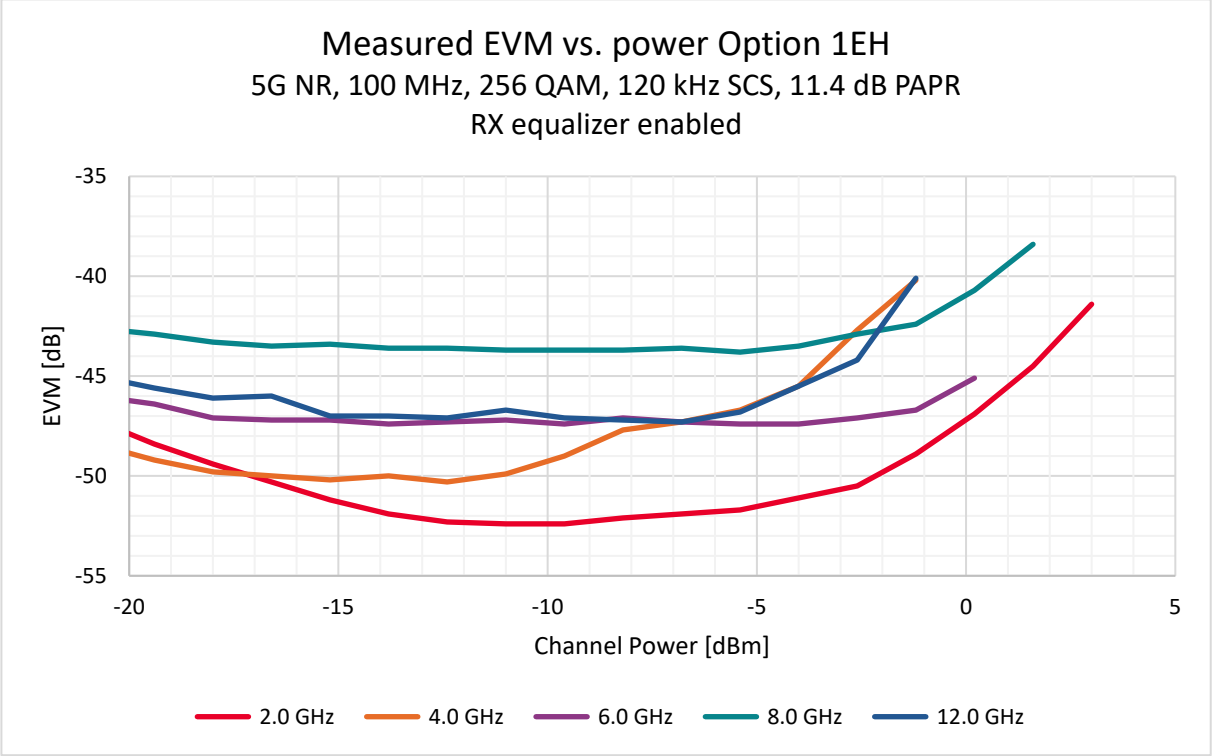


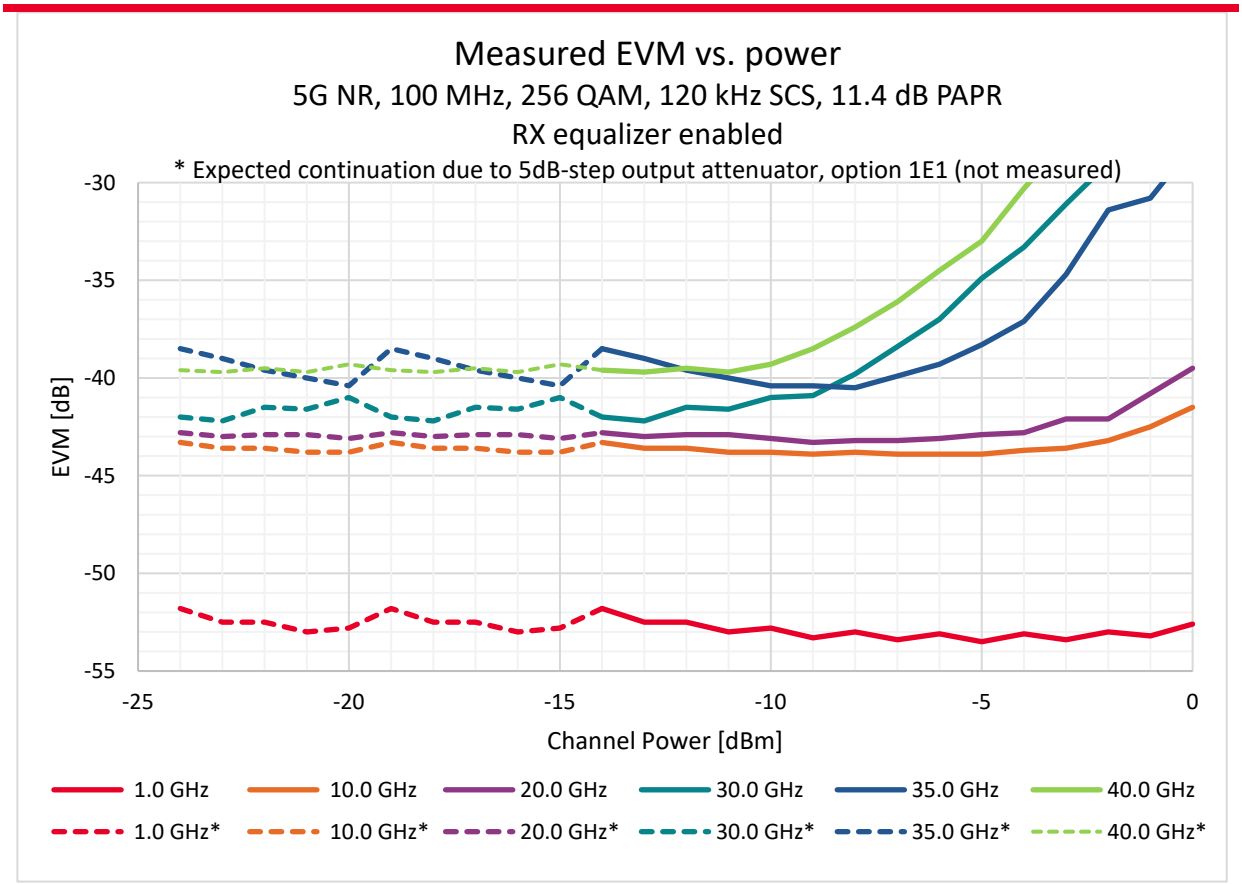


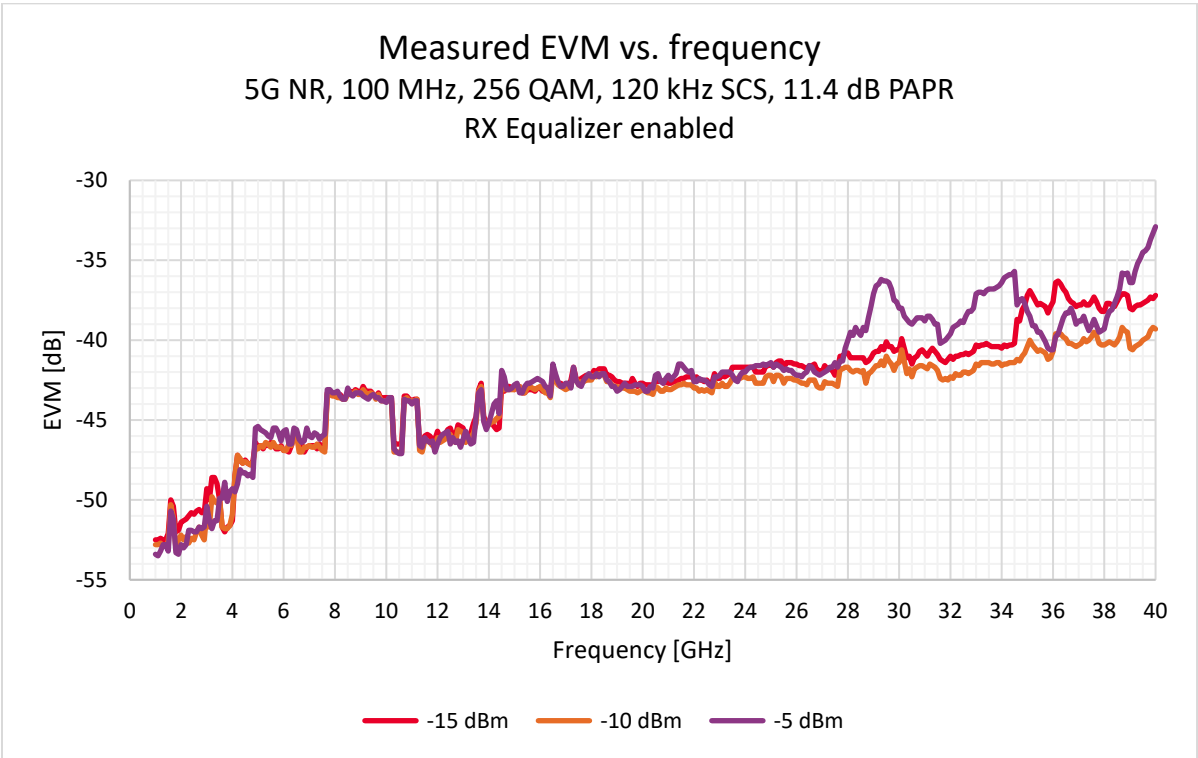

Measured EVM vs. power
5G NR, 100 MHz, 256 QAM, 120 kHz SCS, 11.4 dB PAPR
RX equalizer enabled
EVM [dB]
-35
-40
-45
-50
-55
-20
-15
-10
-5
0
5
Channel Power [dBm]
2.0 GHz
4.0 GHz
6.0 GHz
8.0 GHz
12.0 GHz


Measured EVM vs. frequency
5G NR, 100 MHz, 256 QAM, 120 kHz SCS, 11.4 dB PAPR
RX equalizer enabled
EVM [dB]
-35
-40
-45
-50
-55
0
2
4
6
8
10
12
Frequency [GHz]
-15 dBm
-10 dBm
-5 dBm
0 dBm

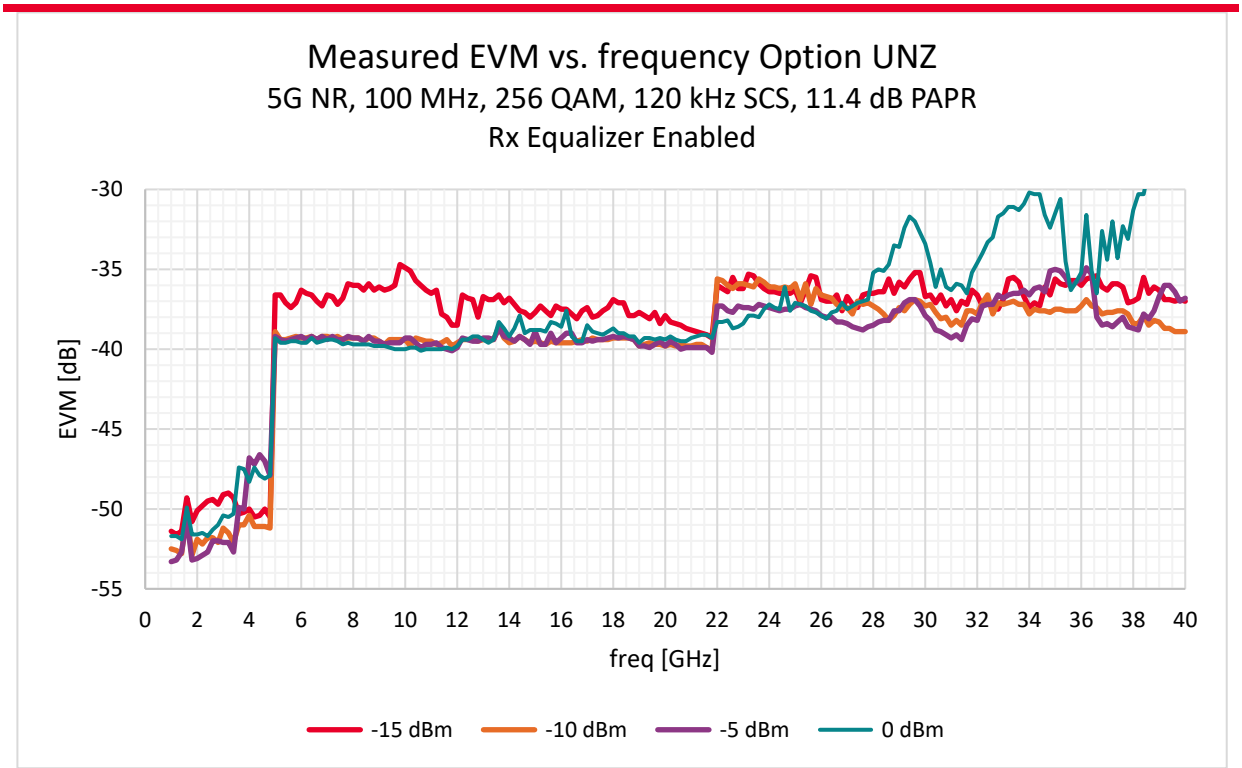

Measured EVM vs. frequency Option 1EH
5G NR, 100 MHz, 256 QAM, 120 kHz SCS, 11.4 dB PAPR
Rx Equalizer Enabled
EVM [dB]
-35
-40
-45
-50
-55
0
2
4
6
8
10
12
freq [GHz]
-15 dBm
-10 dBm
-5 dBm


Measured EVM vs. power Option 1EH
5G NR, 100 MHz, 256 QAM, 120 kHz SCS, 11.4 dB PAPR
RX equalizer enabled
EVM [dB]
-35
-40
-45
-50
-55
-20
-15
-10
-5
0
5
Channel Power [dBm]
2.0 GHz
4.0 GHz
6.0 GHz
8.0 GHz
12.0 GHz

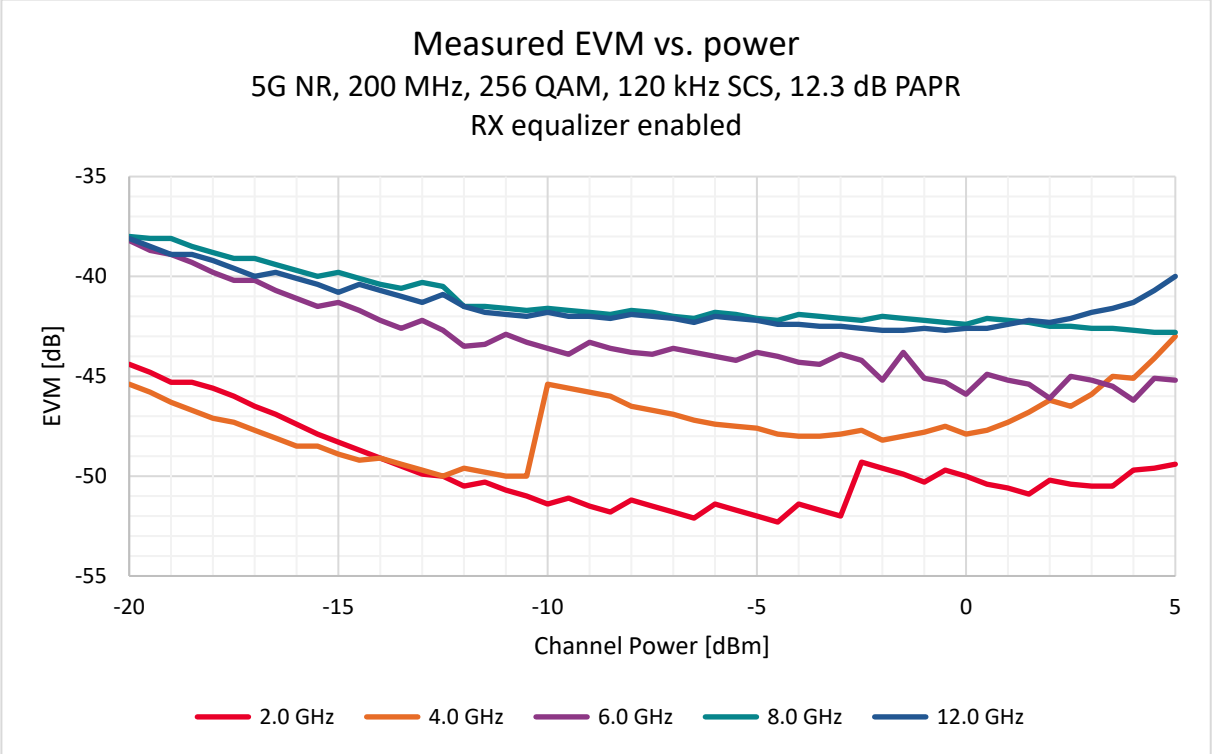

Measured EVM vs. power
5G NR, 100 MHz, 256 QAM, 120 kHz SCS, 11.4 dB PAPR
RX equalizer enabled
* Expected continuation due to 5dB-step output attenuator, option 1E1 (not measured)
EVM [dB]
-30
-35
-40
-45
-50
-55
-25
-20
-15
-10
-5
0
Channel Power [dBm]
1.0 GHz
10.0 GHz
20.0 GHz
30.0 GHz
35.0 GHz
40.0 GHz
1.0 GHz*
10.0 GHz*
20.0 GHz*
30.0 GHz*
35.0 GHz*
40.0 GHz*


Measured EVM vs. frequency
5G NR, 100 MHz, 256 QAM, 120 kHz SCS, 11.4 dB PAPR
RX Equalizer enabled
EVM [dB]
-30
-35
-40
-45
-50
-55
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Frequency [GHz]
-15 dBm
-10 dBm
-5 dBm

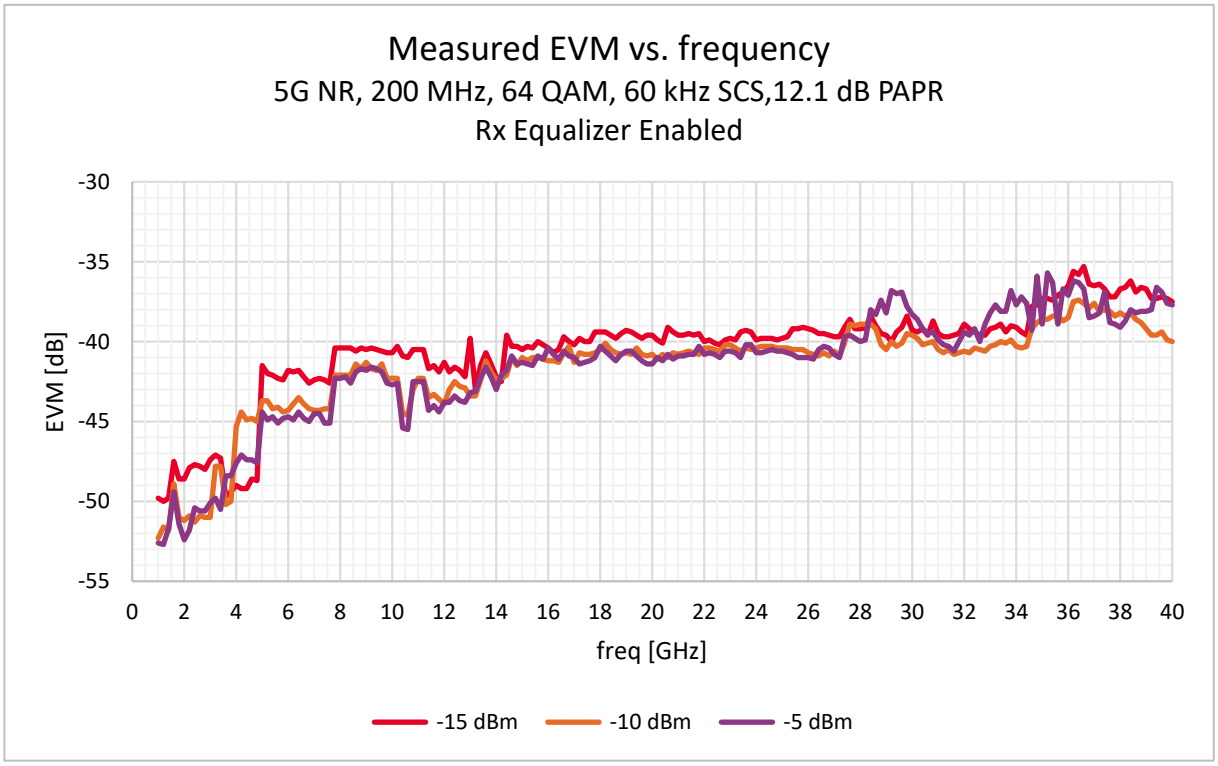
EVM for 5G NR 100 MHz Bandwidth, Measured (Option 506 to 540 with UNZ)



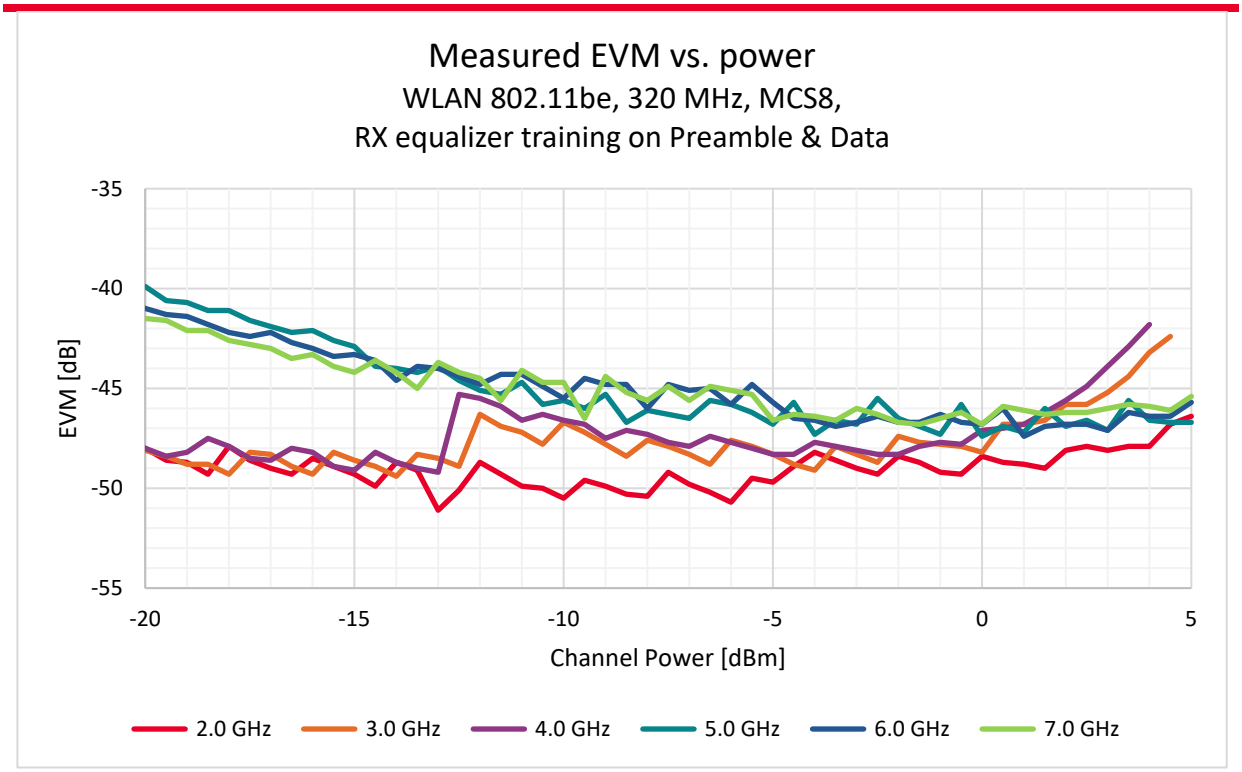
EVM for 5G NR 200 MHz Bandwidth, Measured (Option 504 to 512)

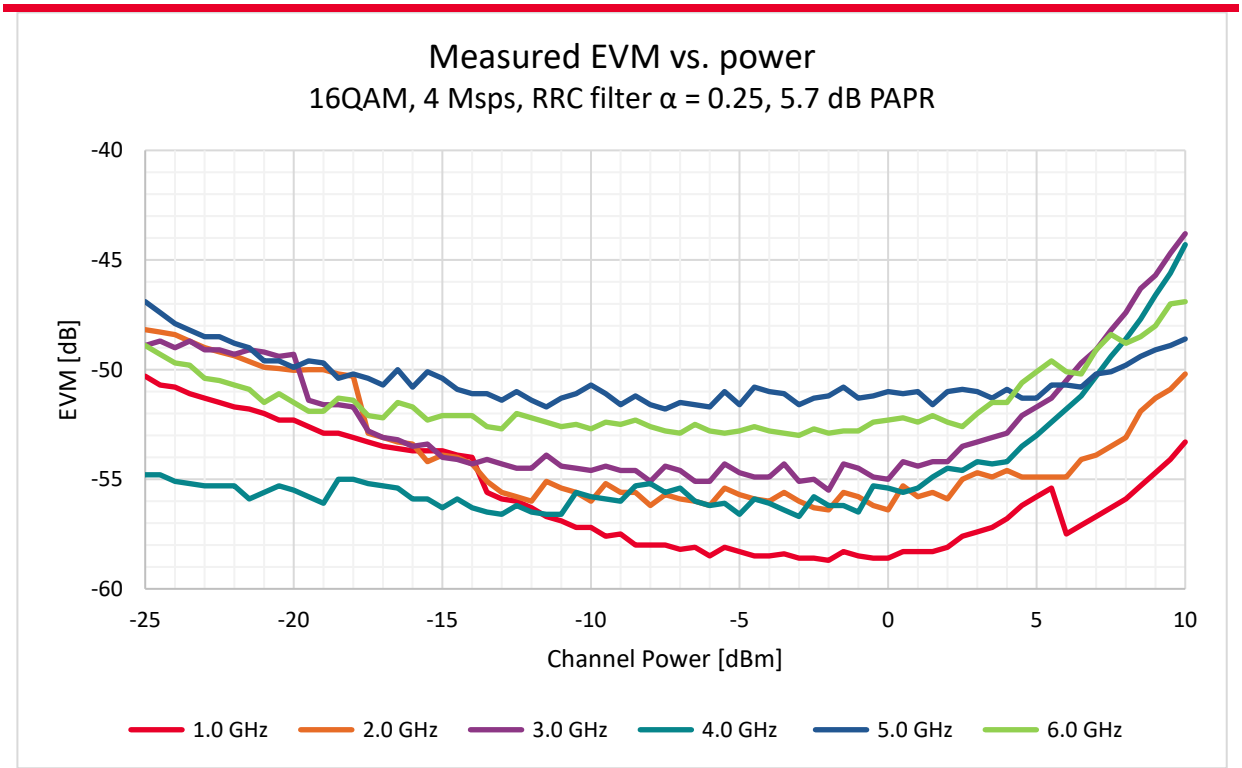


EVM for 5G NR 200 MHz Bandwidth, Measured (Option 506 to 540)



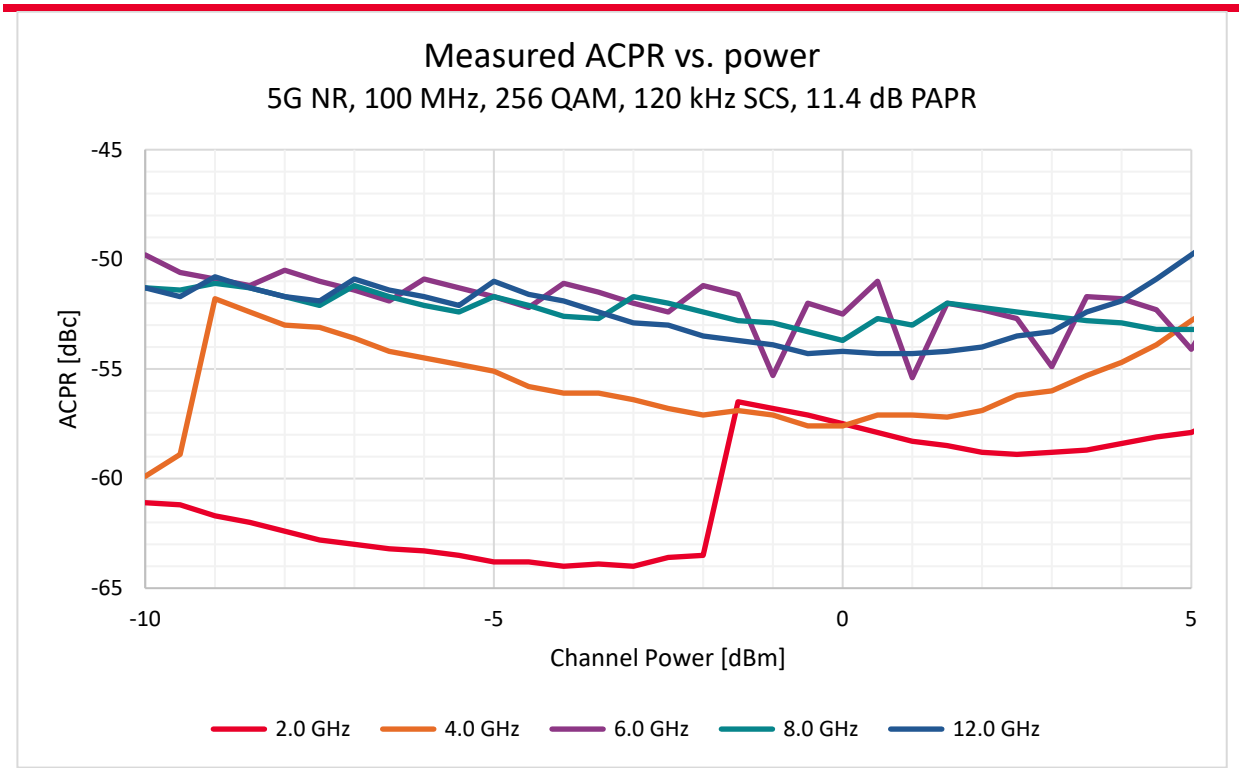
EVM for WLAN 802.11be, Measured (Option 504 to 512)




Measured EVM vs. power
16QAM, 4 Msps, RRC filter α = 0.25, 5.7 dB PAPR
EVM [dB]
-40
-45
-50
-55
-60
-25
-20
-15
-10
-5
0
5
10
Channel Power [dBm]
1.0 GHz
2.0 GHz
3.0 GHz
4.0 GHz
5.0 GHz
6.0 GHz

Distortion Performance (ACPR)

ACPR for 5G NR 100 MHz Bandwidth, Measured (Option 504 to 512)



External Multi-Function Inputs and Outputs (MF)

Digital Inputs (MFI1 IN, MF2 IN)

Connector type	SMB (m)
Input impedance (nom)	10 kΩ DC and 50 Ω AC
Input voltage range (nom)	0 to 3.3 V
Input damage level	≤ –0.5 V and ≥ +5.5 V
Threshold voltage (nom)	0.9 V

Digital Outputs (MFI1 OUT, MF2 OUT)

Connector type	SMB (m)
Output impedance (nom)	50 Ω
Output voltage range (nom)	0 to 3.3 V
Input damage level	≤ –0.5 V and ≥ +5.5 V

External Analog Inputs (Option EXT)

Analog Inputs (I IN, Q IN)

Connector type	SMB (m)
Input impedance (nom)	50 Ω
Input voltage range (nom)	-0.5 V to +0.5 V
Input damage level	< -2 V and > +2 V
Analog bandwidth (meas)	50 MHz
Operation modes	Analog I/Q modulation, External AM, FM modulation (Opt. UNT)
Additional features	Individual digital gain and DC offset adjustment, overrange detection

Fast Control Port (Option FCP)

For fast, time critical settings and data streaming the Vector Signal Generator can be controlled over an optional external fast control port. The FCP system can only be configured over SCPI and the PC software.

Fast Control Port	
Interface	18 bits parallel LVDS receiver with 100 Ω termination
Operation modes	I/Q data streaming, waveform segment ID streaming
Connector type	36-pin mini-D, MDR

I/Q Data Streaming Over FCP	
I/Q sample rate	125 or 250 MHz
Data format	data (16 bits), clock, valid signal

Waveform Segment ID Streaming Over FCP	
Sample rate	250 MHz
Data format	data (16 bits), valid signal

SD Card (Option 006)

Removable solid-state memory (micro-SD card) from rear panel. The SD card is not included. Used only for non-volatile I/Q waveform files (.QID, .QIM, .WFM).[11]

SD Card	
Supported SD	Up to 2 GB with FAT 12 or FAT 16
Supported SDHC	Up to 32 GB with FAT 32

11 Not hot plug capable (must be inserted before Instrument is powered on)

Remote Programming

Remote Programming

Interfaces	LAN 1000BaseT LAN interface USB Version 2.0 GPIB IEEE-488.2,1987 with listen and talk (Opt. GPB)
Control language	SCPI Version 1999.0

Software Compatibility

AP504XA VSG GUI	PC software to control the instrument
Signal Studio	Various applications supported (see AP504xA configuration guides)
IQ tools	Flexible waveform generation tool for AP504xA, version ≥ 1.0.0.0
VSA2026	Keysight 89600 Vector Signal Analyzer software (future)

Software AP504XA VSG GUI - Hardware Requirements

CPU architecture:	X64
Memory	2 GB
Storage	380 MB
Recommended display resolution	Full HD 1920x1080
Ports	Ethernet or USB
Supported OS:	Windows 10 or newer

Software AP504XA VSG GUI – Supported I/Q-Waveform File Formats

Type	Extension	Remarks
Quadrature In-phase Extended Data	.qid	Metadata found in accompanying .qim file. (for further information see application note Vector Signal Generator - IQ Data Format and Device Upload)
Quadrature In-phase Binary Data	.qi	
In-phase Quadrature Data	.iq	
Comma Separated Values	.csv	Supported Configurations: Delimiter: ';', ',' Decimal separator: '.', ',' Data format: '0 to 65535', '-1 to 1' Data orientation: 'vertical', 'horizontal'
Anritsu Quadrature In-phase Data	.wvd	
Keysight 16-bit I/Q pairs	.keysight	LSB first
NI TDMS	.tdms	
R&S IQ Tarball	.tar	
Keysight Waveform	.wfm	
Matlab Data	.mat	Supports a list 'Y' of complex numbers. The real part of the number is I, the imaginary part of the number is Q. Can be generated in Keysight IQTools.

Software AP504XA VSG GUI – Limitations

Number of PDWs in list editor	1 to 1,000
Number of PDWs in bulk upload (.csv)	1 to 1 M

General Specifications

Physical Specifications (AP5041A)

Weight	Opt. 504 Opt. 506, 512, 520, 540	< 6.5 kg < 7.5 kg
Dimensions	Height incl. feet Height without feet	96.8 mm 83 mm
	Width incl. front handles Width without front handles	244 mm 224 mm
	Length incl. connectors (opt. 504, 506, 512) Length incl. connectors (opt. 520, 540) Length incl. Connectors and front handles	391.3 mm 393.4 mm 418.5 mm
Display	Resolution Size	800 x 480 5 in (12.7 cm) diagonal

Physical Specifications (AP5042A)

Weight		< 22.5 kg
Dimensions	Height	88 mm
	Width	444 mm
	Length incl. connectors	594 mm

Power Requirements (AP5041A)

Power requirements	100-240 VAC, 50/60 Hz, 150 W Max (Opt. AC1) 100-240 VAC, 50/60 Hz, 165 W Max (Opt. DC1), if external, supplied 24 VDC power adapter used or 24 VDC, 6A Max (Opt. DC1)	
Average power consumption (meas)	Opt. 504 Opt. 506, 512, 520, 540	70 W 90 W

Power Requirements (AP5042A)

Number of Channels	Frequency Option	Power Requirements	Average Power Consumption (Measured)
1 (Opt. 001)	Opt. 504 Opt. 506, 512, 520 ,540	100-240 VAC, 50/60 H 350 W Max	60 W 80W
2 (Opt. 002)	Opt. 504 Opt. 506, 512, 520 ,540		100 W 140 W
3 (Opt. 003)	Opt. 504 Opt. 506, 512, 520 ,540		140 W 180 W
4 (Opt. 004)	Opt. 504 Opt. 506, 512, 520 ,540		180 W 220 W

Environmental Specifications

Operating ambient temperature range	0 to +45 °C
Storage ambient temperature range	-40 to +70 °C
Operating and storage altitude	up to 15,000 feet / 4600 m
Indoor use	For indoor use only
Humidity	Relative humidity range: 20 to 85%RH

Safety, EMC

Safety complies to applicable safety regulation IEC/EN 61010-1.
This product complies with directive 2011/65/EU.
CE notice EMC complies to EMC regulations and directives for emission and immunity to interference (EN 61326-1 Industrial, EN/IEC 61326-2-1).

Recommended Calibration Cycle

2 years