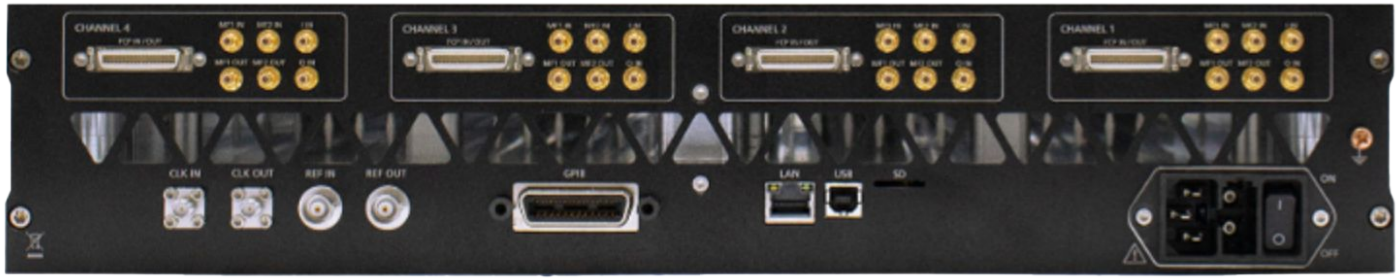
Berkeley Nucleonics Corporation

Multi-Channel VSG Considerations

Model 875 4 Channel Vector Signal Generator
vs
Model N5193 with N5194 Vector Adapter

Model 875-4-40 40 GHz, 4 Channel Vector Signal Generator

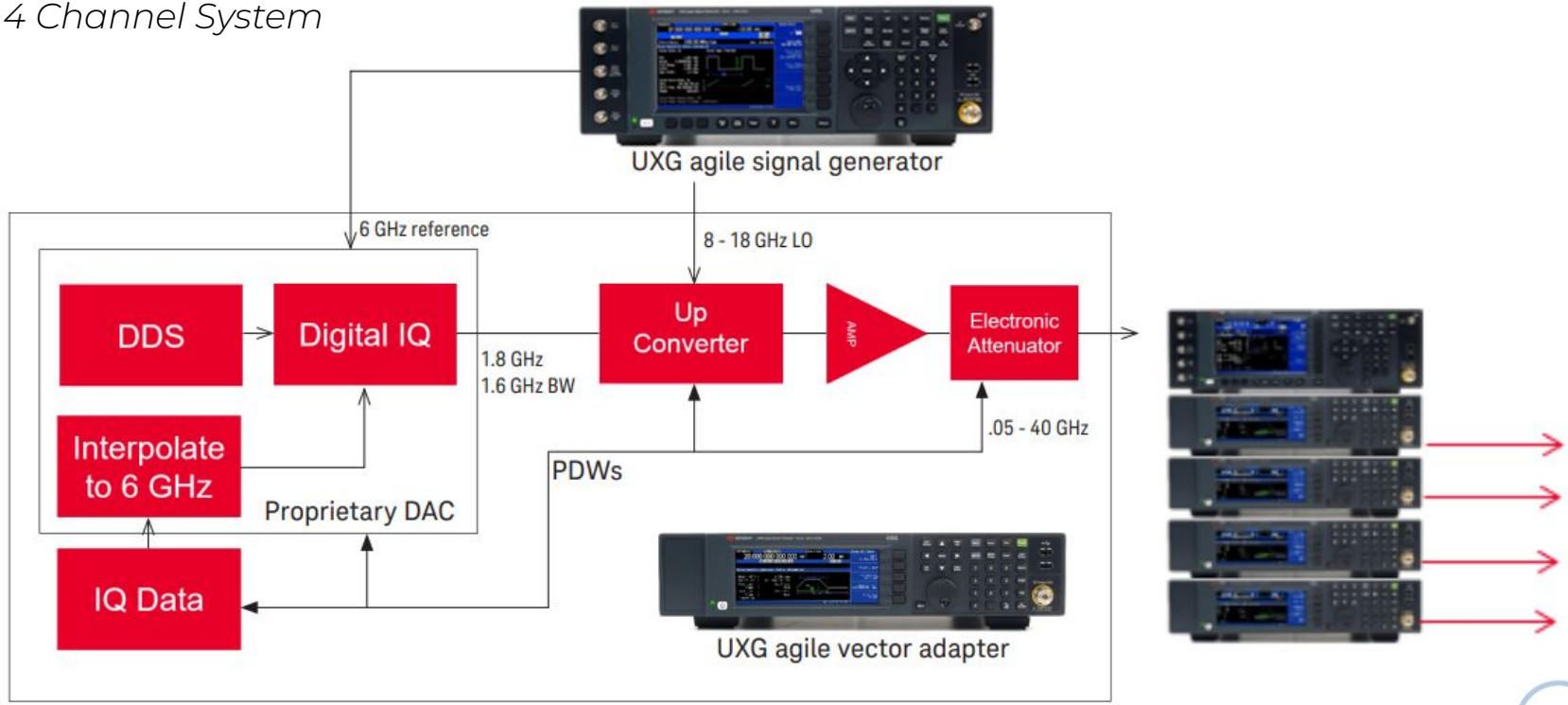
Front Panel



Rear Panel

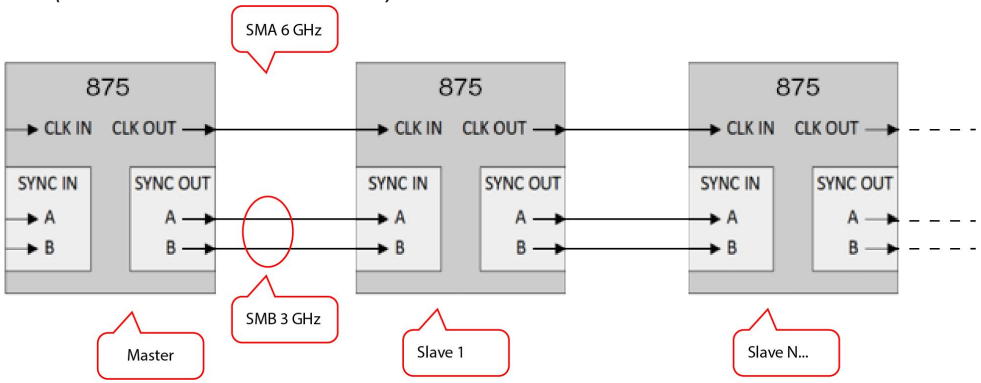
Keysight Model N5193A + 4ea Model N5194A

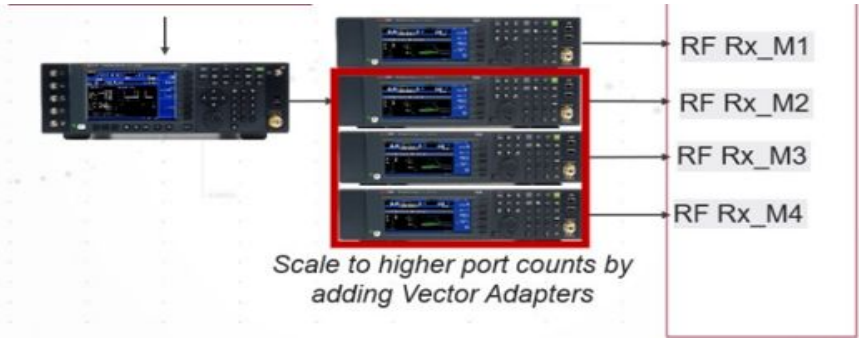
4 Channel System



Multi-Channel Configuration

875 (4 channels / unit) vs. N5193A & N5194A





The reference clock uses SMA connectors.
Connectors and cable must support at least 6 GHz bandwidth.
The synchronization signals A, B, C use SMB connectors.
Connectors and cables must support at least 3 GHz bandwidth.
The N5193A UXG agile signal generator's ability to fast frequency hop with phase continuity and repeatability makes it an ideal building block to efficiently simulate complex threat environments across the full 40 GHz range.

The N5194A UXG vector adapter has a 1.6 GHz bandwidth baseband generator to add more capability to simulate complex electromagnetic environments across the full 40 GHz range. The digital IQ baseband system in the UXG Vector Adapter enables you to create more complex pulses with variable rise/fall times and arbitrary modulation within the pulse, including non-linear chirps and comms signals.

Model	875	N5193A + N5194A
Basic Signal Quality Characteristics		
Frequency Range	100 kHz to 12, 20, 40 GHz	10 MHz to 20, 40 GHz
Number of channels in one unit	**1-2-3-4**	**1**
Scaling	**4-8-12-16 channels**	**N5193A can support only 4 N5194A**
Aging per year	**1 ppm, 0.03 ppm, 0.02 ppm**	**95 µs standard, 1-31 µs Option SS1, 180 ns- 2.9 µs option SS4**
Switching speed analog part	**500 µs standard, < 2 µs UFS option**	**95 µs standard, 1-31 µs Option SS1, 180 ns- 2.9 µs option SS4**
Switching speed digital part	**500 µs standard ,< 1 µs UFS option**	**250 ns N5194A**
Min. power	-120 dBm (mechanical attenuator) -55 dBm electronic attenuator	65 dB Electronic agile attenuator + 0-85 Mechanical step attenuator, total -130 dBm
Max. power, typical	w/o Attenuator [with Attenuator] (dBm)	External LO mode (dBm)
1 GHz	**>+20 [+18]**	**+3**
6 GHz	**>+20 [+18]**	**+3**
10 GHz	**>+20 [+18]**	**+3**
20 GHz	**>+20 [+18]**	**+1**

Model	875	N5193A + N5194A
Level Accuracy -20 dBm to Max	0.7 - 1.2 dB	2.5 dB
Phase noise 1 GHz-- 10 Hz offset (options) 20 kHz offset	-84 dBc/Hz (option LN or LN+) -145 dBc/Hz	10 Hz not specified!! -132 dBc/Hz External LO mode
Phase noise 10 GHz|20 10 Hz offset (options) 20 kHz offset	-66|-76 dBc/Hz (option LN or LN+) -115 dBc/Hz	10 Hz not specified!! -109 dBc/Hz External LO mode
Phase noise 20 GHz 10 Hz offset (options) 20 kHz offset	-60|-70 typ. option LN or LN -115 dBc/Hz	10 Hz not specified!! -106 dbc/Hz External LO mode
Non-Harmonics, >10 kHz offset 1|6|10|15|20 GHz	-90|-70|-60|-60 dBc	-68|-55|-53|-50 dBc Only typical values in DS -72|-64|-64|-64 typical values for IQ BW 400 and 1.6 GHz
Harmonics	-45 dBc	-55 dBc

Model	875 	N5193A + N5194A 
PHASE COHERENCE PERFORMANCE		
Number of Channels	1-2-3-4	1 + 4 ext.
Phase-Coherence Between Channels	Yes	Yes
Phase Coherent Frequency Switching	Yes	Yes
Multi-Channel Baseband Synchronization primary/secondary	Yes	Yes
Phase Calibration	Yes	N/A
Relative Phase Stability	See plots at end of presentation	No info in Datasheet!
Phase Calibration Option (PCM)	Yes	Hardware calibration (Phase, Amplitude): PXI VNA or USB VNA Hardware calibration (time domain): VNA or oscilloscope Thermal control calibration: Recommended Time for calibration 1-2 hours Calibration SW: N7665C

Model	875	N5193A + N5194A
Pulse Modulation Min. Width / Rise Time	0-10 ns| 5 ns typ.	4.0 ns (nom), not guaranteed
Minimum Pulse Width w/ ALC On	8 ns	8 ns
PDW		
Pulse Description Word (PDW)	Supported	Supported
Pulse Description Streaming	Internal SSD External Source: FCP	Internal SSD External source LAN LDVS Port only for N5193A!!
IQ MODULATOR PARAMETERS		
Bandwidth, IQ	400 MHz	200 MHz, 400 MHz and 1.6 GHz
Frequency Response	<± 1,0 dB typ	Not Specified
Carrier Leakage	Su	Not Specified
Suppression of Image Sideband in Modulation Bandwidth	-85 typ, -65 dBc	Not Specified

Model	875	N5193A + N5194A
BASEBAND GENERATOR		
Bandwidth	400 MHz- Standard	200 MHz- standard 400 MHz- option BB2 1.5 GHz- option BB1
Sample-Rate	500 MHz	250 MHz standard 2 GHz option BB1, BB2
Memory of BB Generator (Playback)	512 Msample-Standard	250 MSa-standard 6 GSa per channel optionally
Symbol Rate	10 s/s to 200 MS/s	Not Specified
EVM 16QAM **2.5 GHz, 0 dBm**	0,4% typ	Not-Specified
BASEBAND GENERATOR (SEGMENTED MEMORY MODE)		
Number of Segments	1 to 65k	65k
Sequencer Play List Length	1 to 2048	Not Available
Sequence Segment Repetitions	1 to 10 M	Not Available

Model	875	N5193A + N5194A
	MULTI-TONE MODE	
Number of Carriers	1 to 1000	Not Available
Frequency Offset	-200 to 200 MHz	Not Available
Power Offset	-60 dB to 0 dB	Not Available
	ADDITIVE WHITE GAUSSIAN NOISE	
Crest Factor	≤ 21.07 dBm	Not Available
Carrier to Noise Ratio C/N	-60 to 90 dB	Not Available
	SOFTWARE	
Digital Modulations	Supporting alternative libraries in the format .qid, .qim, .qis, .qi	N7660C Multi-emitter scenario generation SW, Z9500A simulation View for dynamic hardware

Comparison of Technologies

	BNC 875	Keysight N5193A + N5194A	Remarks
Types of Signal Sources	**DDS + Analog VCO**	**DDS**	DDS has advantages in fast-switching, resolution, and because of the digital structure it's easy to control phase for phase-coherent performance. The drawbacks of DDS high Spurs and relatively bad phase noise close to the carrier (close-in). High-frequency range DAC is very expensive, causing high cost of DDS SG. ***Because of the combination of VCO and DDS technologies, the Model 875 has lower spurs and better phase-noise in close-in carriers offset.*** ***Saving all advantages found in DDS like Fast-Switching speed, phase-coherence leveling between channels and frequency resolution.***
Method of Creating Phase Coherence System 4 Channel	**4 Channels in one enclosure with shared reference and phase feedback loop**	**N5193A Master unit shared LO for vector adapters N5194A**	The Keysight Shared LO techniques had some **Disadvantages** The electrical length of the LO signal to the slave generator is different, which leads to phase drift with temperature. This may be why in the Keysight datasheet , the system does not provide data on phase stability relative to 1-10 hours of operation 1. The system does not exclude the additive phase noise of other system components. Therefore, the phase noise of the solution is not normalized to less than 10 kHz offset. 2. Power level of shared LO is different 3. Unable to set coherent frequencies outside the baseband generator band 4. The capacity of the common local oscillator decreases with a larger number of channels, and scalability is limited. The second consequence may be problems with accurately setting the power level on each channel **Advantages of shared LO-system** 1. Performance better than shared reference 10/100 MHz 2. Phase-noise of synthesizer (LO) is correlated

Comparison of Technologies

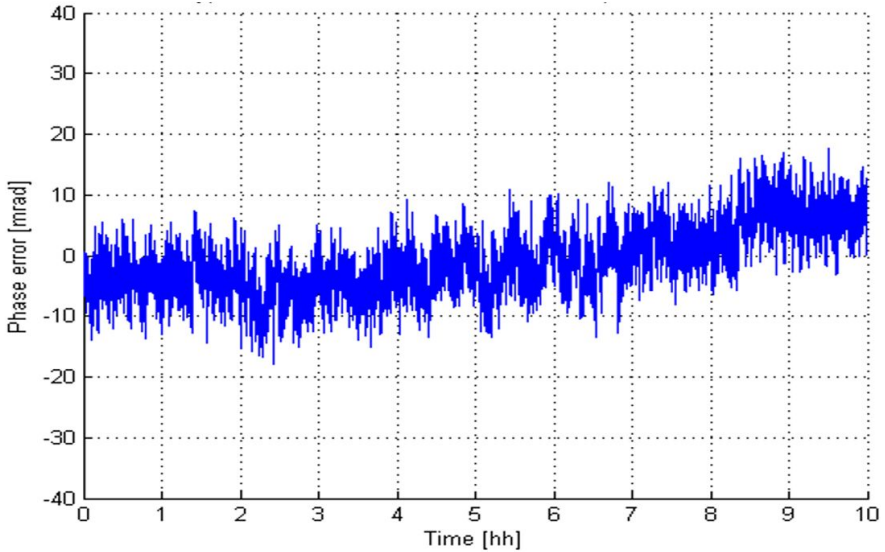
	BNC 875	Keysight N5193A + N5194A	Remarks
Method of creating phase coherence system 4 channel	**4 channels in one enclosure with shared reference and phase feedback loop**	**N5193A Master unit shared LO for vector adapters N5194A**	BNC 4 channel unit with internal shared reference and phase control digital loop **Advantage** 1. Best in class phase-coherence, specified in datasheets between channels and between units. 2. Possible synchronization of 12 or more channels.
Baseband Architecture	**Digital**	**Digital**	Digital baseband architecture provides better in Band-Distortion like Carrier Leakage, Image sideband rejection. Keysight Datasheet for the N5194A does not specify this parameters however. For Model 875 it is specified.
Attenuator	**Electronic PE4 Mechanical PE2**	**Only Electronic**	Electronic attenuator used for fast amplitude setting time. Keysight has wider range of Electronic attenuator settings down to -120 dBm but the maximum power level is only +3 dBm. BNC offers electronic attenuator down to -55 dBm and mechanical down to -120 dBm and max power of BNC is > +15 dBm with either type of attenuator.

Comparison of Technologies

	BNC 875	Keysight N5193A + N5194A	Remarks
Phase Calibrate Mode	**Available**	**Not available, Supplier offers calibration SW and VNA**	Model 875 with Option PCM: This enables true zero phase offset between channels over any frequency / power range (up to a device's full power and frequency range). ***Advantages of PCM*** ● Static phase relationships over power level. ● Linear phase relationships over frequency. ● Phase calibration (or correction) over a larger or even the full power and frequency range is possible with only a few calibration (correction) points. ● PCM has no impact on switching speed. ● PCM is fully supported in ultra fast switching (UFS) mode, for example with pulse descriptor word (PDW) playback. ***Limitations of PCM*** ● IQ scaling reduces IQ dynamic range

Phase Coherence at 38 GHz

BNC Model 875 at 38 GHz



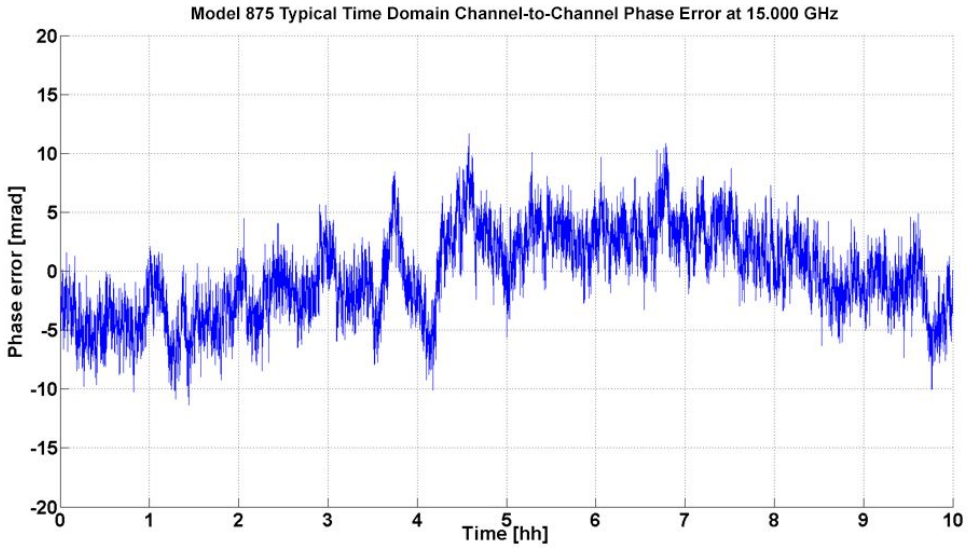
Keysight N5193A+N5194A

NO DATA

The Maximum amplitude of phase deviation BNC Model 875 at 38 GHz in 10hr run is 25 mrad or 1.43 Degree.

Phase Coherence at 15 GHz

BNC Model 875 at 15 GHz



Keysight N5193A+N5194A

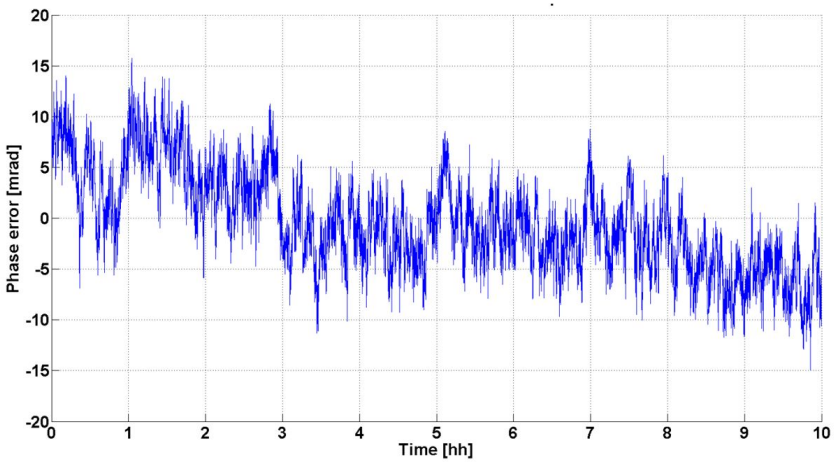
NO DATA

The Maximum amplitude of phase deviation BNC Model 875 at 15 GHz in 10hr run is 20 mrad or 1.15 Degree.

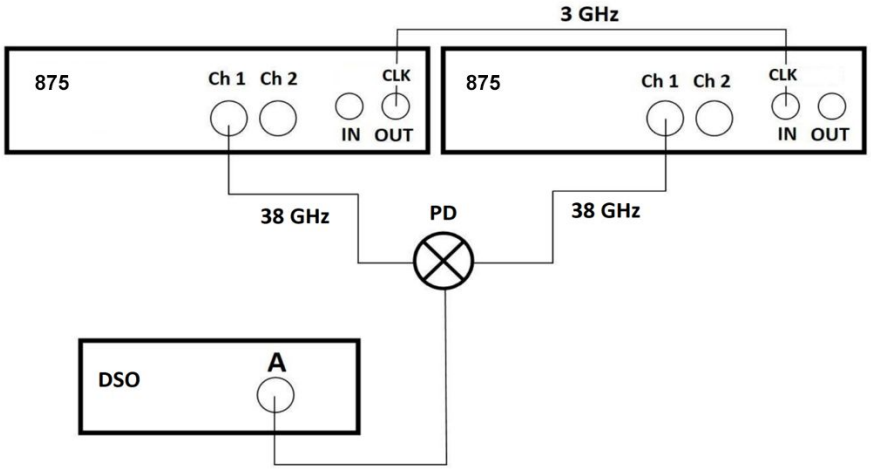
Phase Error

Between synchronized BNC Analog & Vector Multi-Channel Signal Generator

BNC Model 875 and 855B



Measurement Setup

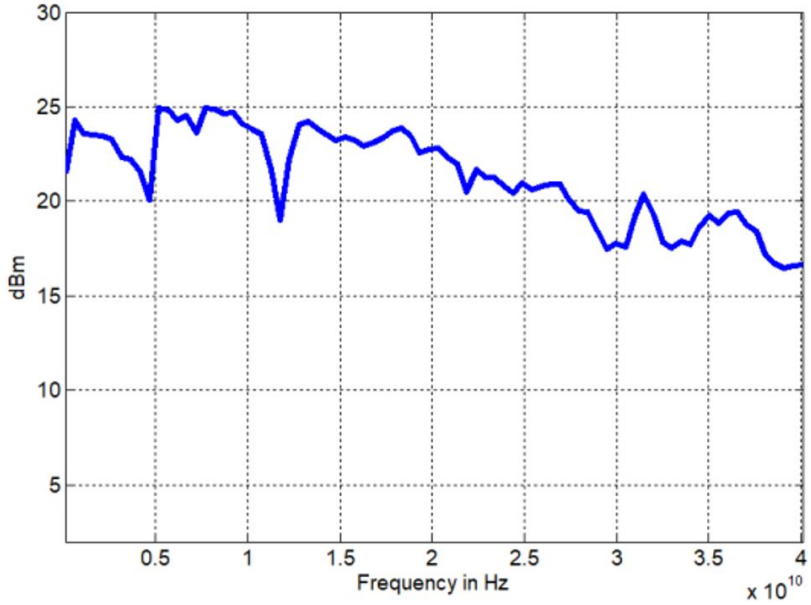


Analog and vector signal sources could be combined in the Multi-Channel phase coherent system.

Maximum Power

BNC vs. Keysight

BNC Model 875



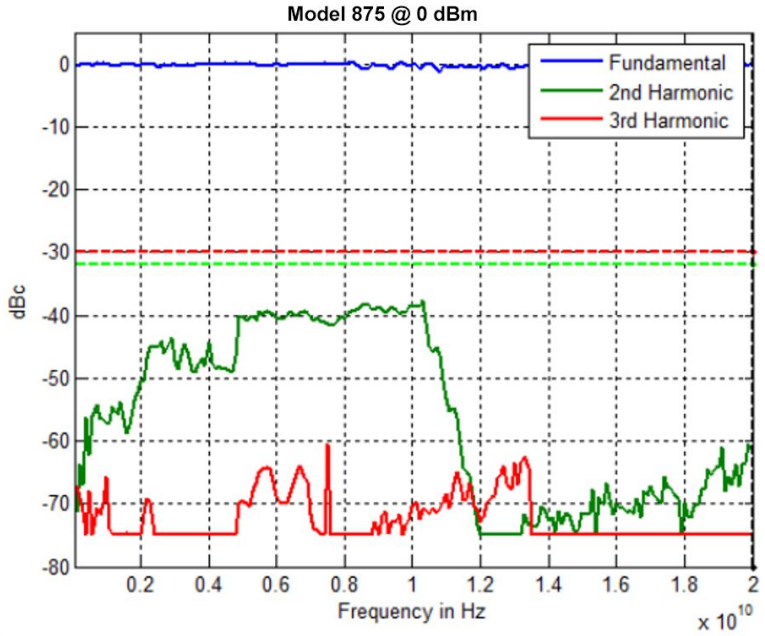
Keysight N5193A + N5194A

Option 520 or 52E	Max specified power	
Frequency	External LO mode, dBm spec	Internal LO mode, dBm spec
10 MHz to < 2.5 GHz	+3	+3
2.5 GHz to 4 GHz	+3	+3
> 4 GHz to 14 GHz	+3	+3
> 14 GHz to 18 GHz	+3	+3
> 18 GHz to 20 GHz	+1	–2

Harmonics

BNC vs. Keysight

BNC Model 875



Keysight N5193A LO to N5194A

Fundamental frequency	Harmonic level (dBc) at 0 dBm or max available power, whichever is lower
10 MHz to < 50 MHz	(–32)
50 MHz to 2 GHz	–30 (–33)
> 2 GHz to 3 GHz	–20 (–24)
> 3 GHz to 4 GHz	–29 (–33)
> 4 GHz to 8 GHz	–58 (–63)
> 8 GHz to 12.5 GHz	–61 (–66)
> 12.5 GHz to 20 GHz	–53 (–59)
> 20 GHz to 22 GHz	(–59)

Keysight has frequency range with performance less than -30 dBc. This could have a negative impact for frequency hopping applications. But in X-band Keysight has better harmonic performance. In overall consideration, the two signal source have parity in this type of performance.

Non-Harmonics

BNC vs. Keysight

BNC Model 875

Non-Harmonic Spurious (at 0 dBm Output, > 10 kHz Offset)				
		-90 dBc	-75 dBc	< 1.2 GHz
		-80 dBc	-70 dBc	1.2 to 2.5 GHz
		-80 dBc	-55 dBc	2.5 to 4 GHz
		-70 dBc	-50 dBc	4 to 12 GHz
		-60 dBc	-50 dBc	12 to 20 GHz
		-55 dBc	-45 dBc	> 20 GHz

Keysight N5193A LO to N5194A

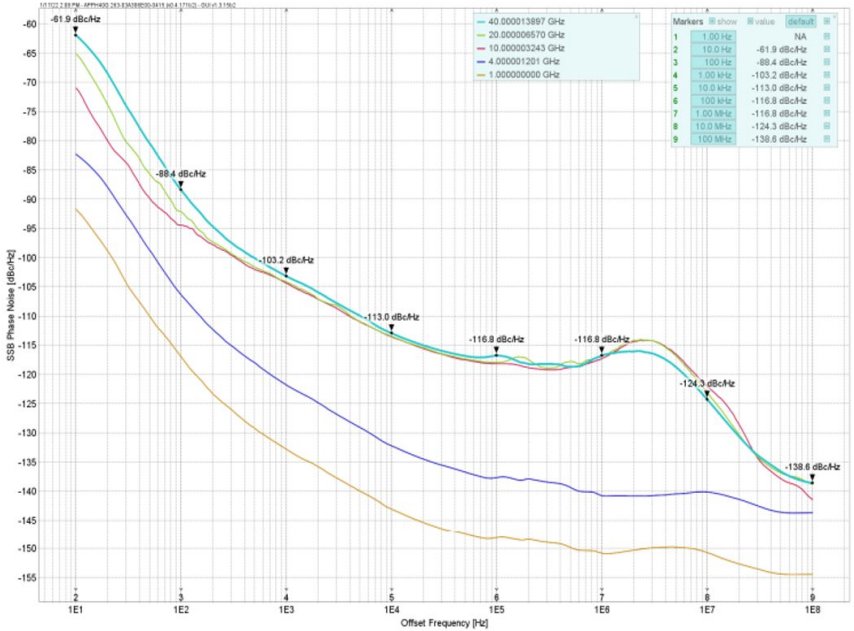
External LO mode, wideband or enhanced vector mode (Opt BB1 or BB2)

	Non–harmonic level (dBc) (typ)		
Frequency	Line–related spurs at offsets ≤ 300 Hz	Offsets > 300 Hz excluding line–related spurs	Offsets > 10 kHz
10 MHz to < 50 MHz	N/A	N/A	N/A
50 MHz to < 1.2 GHz	(–72)	(–72)	(–72)
1.2 GHz to < 9 GHz	(–56)	(–62)	(–64)
9 GHz to < 12.5 GHz	(–53)	(–60)	(–70)
12.5 GHz to 20 GHz	(–49)	(–55)	(–64)

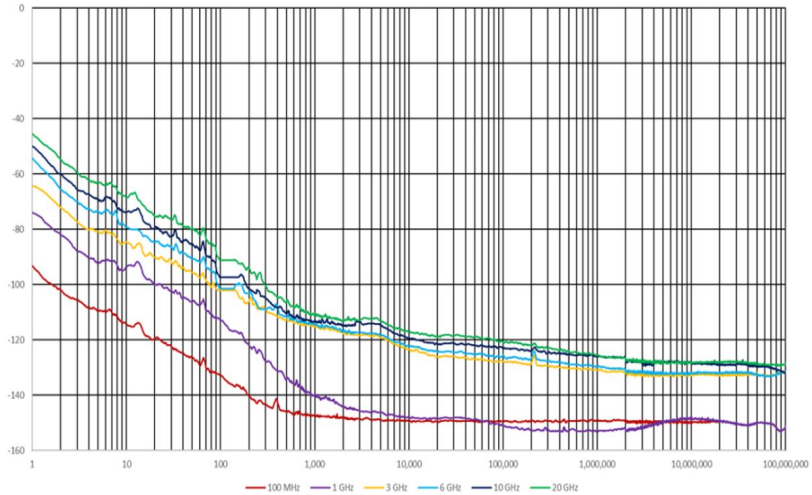
Non-harmonic performance not guaranteed in Keysight's datasheet. Poor performance of Keysight N5193A-N5194A system explained by DDS architecture.

Phase Noise

BNC vs. Keysight



Model 875, w/out option LN (LN option for further improvement)

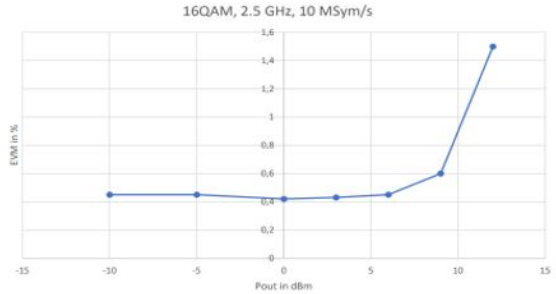


Measured external LO absolute phase noise for N5194A

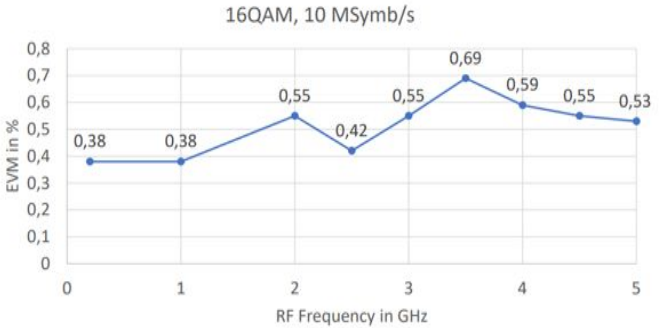
Residual phase noise from vector adaptor N5194A has an impact on the relatively good phase noise of N5193A.
Signal generator used as LO.

EVM 16QAM

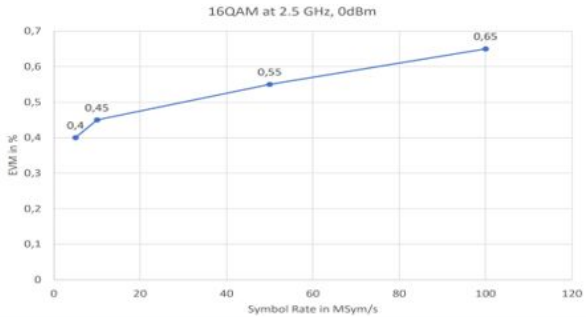
BNC vs. Keysight



Model 875



Keysight N5193A + N5194A

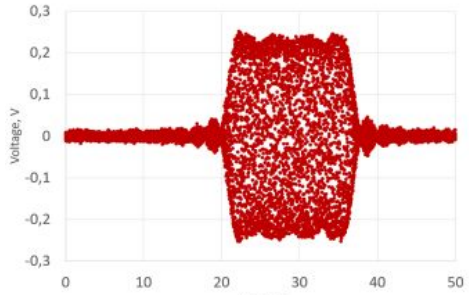


EVM not specified in Keysight's Datasheet

Pulse Modulation

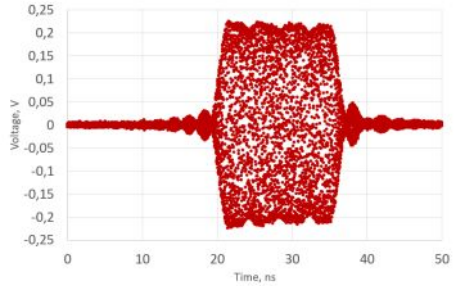
BNC vs. Keysight

Figure 22: Pulse modulation 16 ns at 10 GHz



Model 875

Figure 23: Pulse modulation 16 ns at 40 GHz



Defined by IQ waveform. Minimum rise/fall time

Vector mode	4.0 ns (nom)
Enhanced vector mode (opt BB2)	2.0 ns (nom)
Wideband vector mode (opt BB1)	0.5 ns (nom)

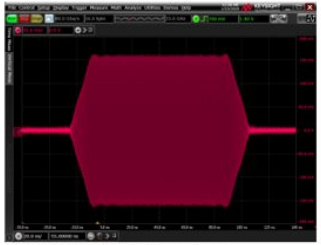


Figure 11. 100 ns pulse with 16 ns rise/fall times.

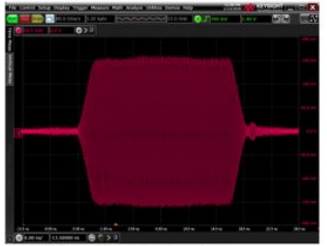


Figure 12. 20 ns pulse with 2 ns rise/fall times.

Overshoot

Vector mode	4 % (typ) up to 32 GHz
Enhanced vector mode (opt BB2) or Wideband vector mode (opt BB1)	10 % (typ) up to 32 GHz [3]

Pulse Width [2]

	Minimum	Maximum
Vector mode	8 ns (nom)	8 ns (nom)
Enhanced vector mode	2 s (nom)	4 ns (nom)
Wideband vector mode	2 s (nom)	1 ns (nom)

In the datasheet for N5194A pulse parameters are not guaranteed and only present nominal values. BNC guarantees pulse-width, both suppliers have plots with high-quality pulse modulation performance.

Conclusion

BNC vs. Keysight

In comparison, Keysight N5193A UXG Analog Signal Source + Vector Adapter N5194A has several advantages over BNC because of our combination of technologies using signal sources based on DDS + Analog VCO. However, the disadvantages of the Keysight solution is driven by the limitations of DDS technology alone and the unsuccessful method of creating a coherent system using a common local oscillator. These restrictions are so significant that a number of important parameters in the Keysight system are not guaranteed in the documentation. Important parameters cannot be found in the Keysight datasheet.

Advantages of BNC:

Signal Quality:

- The number of coherent channels per unit is higher and the system is fully scalable to 12 or more channels. Keysight has a maximum of 4 channels.
- Better long-term stability 0.02 ppm year
- Higher maximum power and level accuracy, BNC (max. power +18 dBm, <1.0 dB error) vs Keysight (+3 dBm, 2.5 dB error)
- Model 875 has better phase noise close to the carrier and in kHz offsets range.
- BNC guaranteed non-harmonics performance and level of performance is better. Keysight does not guaranteed level of non-harmonics.

Phase-Coherence:

- BNC specifies in datasheet phase-coherence performance and provides supportive plots within 10h of operations. In keysight datasheet, limited information about phase coherence performance.
- Phase calibration option - A special feature of BNC avoid a long calibration process

Conclusion

BNC vs. Keysight

IQ Modulation:

- Keysight specifies a higher IQ modulation bandwidth. However, parameters related to the quality of the IQ signals are not mentioned in the datasheet like: frequency response of IQ band, carrier leakage, suppression of image sideband in modulation bandwidth. As an assumption because of a shared LO, all units do not have good performance of IQ band from the vector adapter.

Baseband Generator:

- Despite on the broader baseband generator from Keysight, EVM is not specified.

Advantages of Keysight:

- Switching speed over specific bandwidth
- Broader IQ bandwidth
- Software for advanced signal simulation
- PDW number of pulsed per second bigger, faster upload speed.

Important parameters not specified or not guaranteed in the Keysight datasheet

- Phase-stability over 10 hours and phase-error
- Level of Non-Harmonics (the datasheet only present typical value)
- Phase-noise level before 10 kHz offset
- IQ Modulation quality (Carrier leakage and side-band suppression, Frequency response)
- Baseband generator upscale value of EVM
- Pulse parameters


BNC
Berkeley Nucleonics Corp