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ENOB Measurement of Gsps ADC with Rubidium™ MG362x1A RF/Microwave Signal Generator

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High speed ADCs

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- Remarkable improvement in sampling rate and resolution of ADCs over last few years
  - ADCs with Sampling rate more than 10 Gsps are offered by several vendors
- High speed ADCs drive digitization of signals closer to antennae than ever before in receiver signal processing chains
- High speed ADCs drive instruments such as digital storage oscilloscopes to higher frequencies than ever
- Digitization earlier in receiver signal processing chains enables use of sophisticated DSP techniques to achieve
  - Simultaneous reception of multiple channels
  - Fast channel acquisition
  - Better signal selectivity and better signal detection
- ADCs inherent noise and resulting SNR at its output is critical to performance of receivers and digital storage oscilloscopes

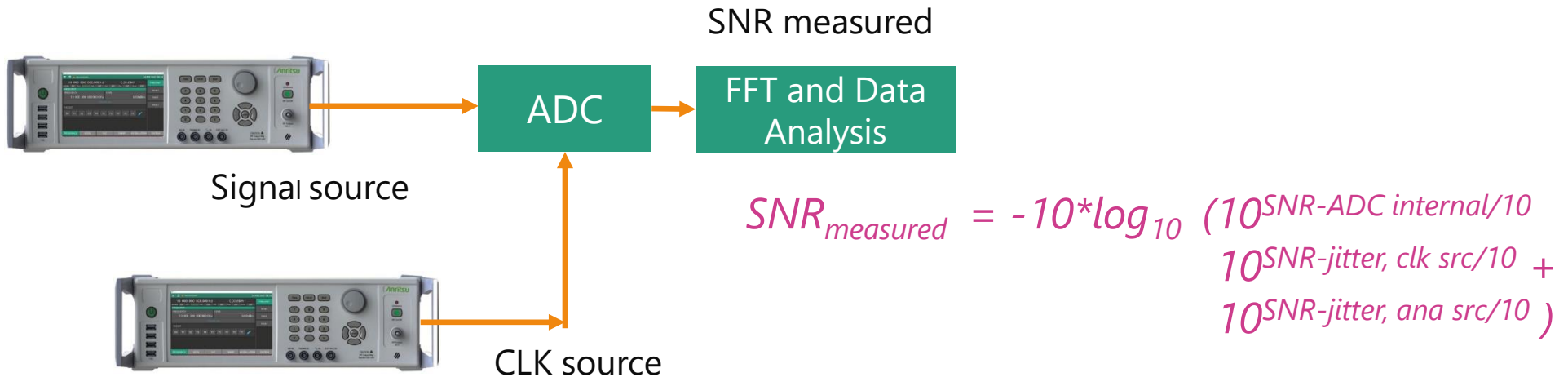
ADC SNR and resolution

- SNR at the output of an ADC is a function of its resolution i.e., number of ADC bits:
  - $SNR_{ADC\ out}$ = 6.02*n + 1.76 dB
    n= number of DAC bits

No of ADC bits	8	10	12	14	16
SNR in dB	50	62	74	86	98

- The SNR above is determined by quantization noise and is under ideal circumstances.
- The real SNR measured at the ADC output is almost always lower than that due to additional noise contributions, which include:
  - **ADC's inherent contributions** such as internal thermal noise, DNL, intrinsic aperture RMS jitter
  - **External contributions by measuring equipment** such as RMS jitter of sampling clock source and signal source
- The signal generators used for measurement must have SNR as low as possible
  - Their contribution to ADC's inherent SNR due to thermal/DNL and intrinsic aperture jitter needs to be minimal

Measuring SNR and ENOB of ADC

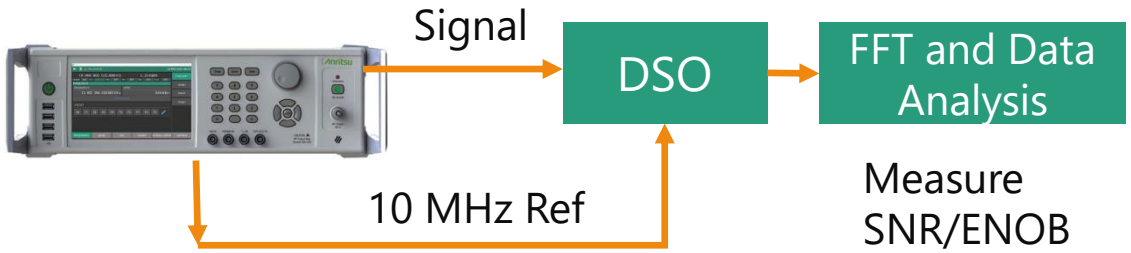


SNR Measurement Setup at ADC output

- Critical performance parameters for SNR measurement are:
  - Integrated phase noise/RMS Jitter and harmonic of signal source
  - Integrated phase noise/RMS Jitter and spurious of clock source
- The effective number of bits (ENOB) is computed from real SNR measured at the output of the ADC as below:

$$ENOB = (SNR_{ADC\ out} - 1.76dB)/6.02$$

Measuring ENOB of High frequency DSO

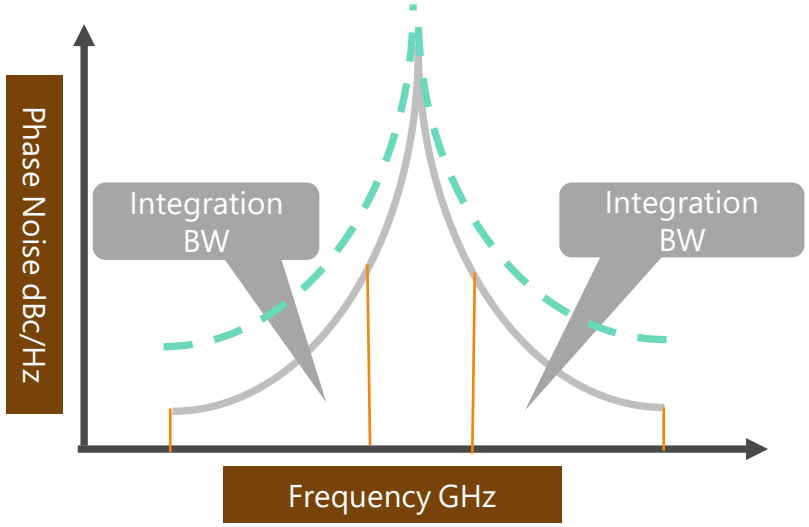


SNR measurement setup for DSO

- Typical DSO measurements include SNR and ENOB at various input frequencies up to 10 GHz and different vertical scale settings
- Critical performance parameters for measurement are:
  - Integrated phase noise and spurious over entire input frequency range of DSO
  - Harmonics and subharmonics over entire input frequency range of DSO

Phase noise integration limits

- Signal and clock sources SNR is dependent on their RMS jitter, which is calculated from integrated phase noise.
- For clock sources, the lower limit of integration bandwidth is typically 10 kHz and upper limit is equal to bandwidth in the clock path.
  - Phase variations at lower than 10 kHz offset do not matter as they are slower than observation time of one FFT shot (typically 64K) and can be ignored for clock frequencies > 1 GHz
- For signal sources, the lower limit of integration is somewhere between 1 kHz to 10 kHz and the upper limit is the nyquist bandwidth (i.e., clock freq/2).
  - The lower limit of integration is dependent on the application in which the ADC is used. For receiver chains, it is close to carrier or timing recovery loop bandwidths as they act as HPF for phase noise



Rubidium™ - A Benchmark in Signal Purity

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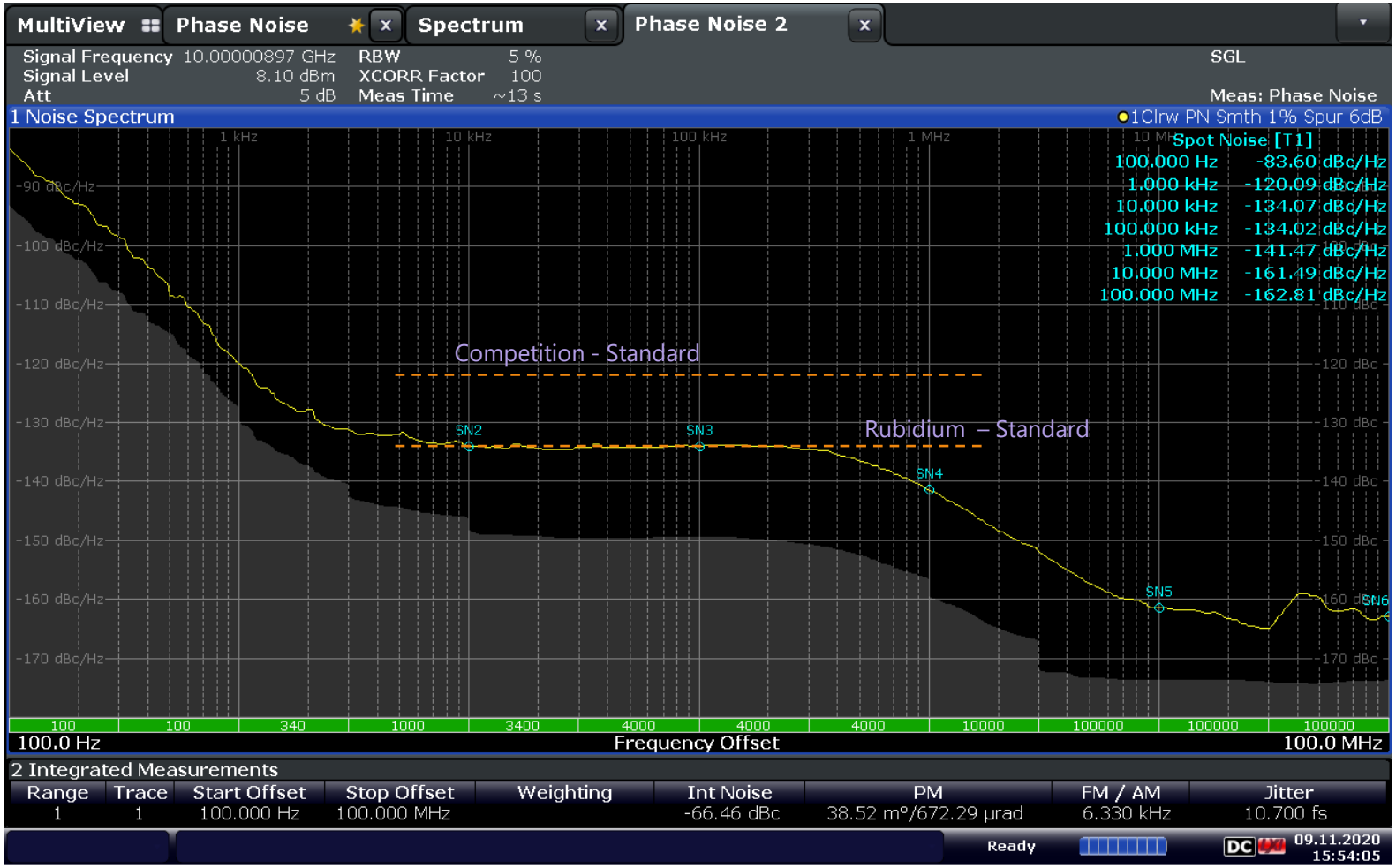
Phase Noise performance between integration BW Limits

SSB Phase Noise Option	10 GHz @ 10 KHz offset (typical)	
	Rubidium™	Competitor Sig Gen
Standard Phase noise	-132 dBc/Hz	-120 dBc/Hz
Low Phase Noise	-133 dBc/Hz	-125 dBc/Hz
Ultra Low Phase Noise	-136 dBc/Hz	-132 dBc/Hz
Premium Phase Noise	-140 dBc/Hz	NA

SSB Phase Noise Option	10 GHz @ 10 MHz offset (typical)	
	Rubidium™	Competitor Sig Gen
Standard Phase noise	-157 dBc/Hz	-148 dBc/Hz
Low Phase Noise	-157 dBc/Hz	-153 dBc/Hz
Ultra Low Phase Noise	-157 dBc/Hz	-160 dBc/Hz
Premium Phase Noise	-163 dBc/Hz	NA

Rubidium™ – Standard Phase Noise (meas)



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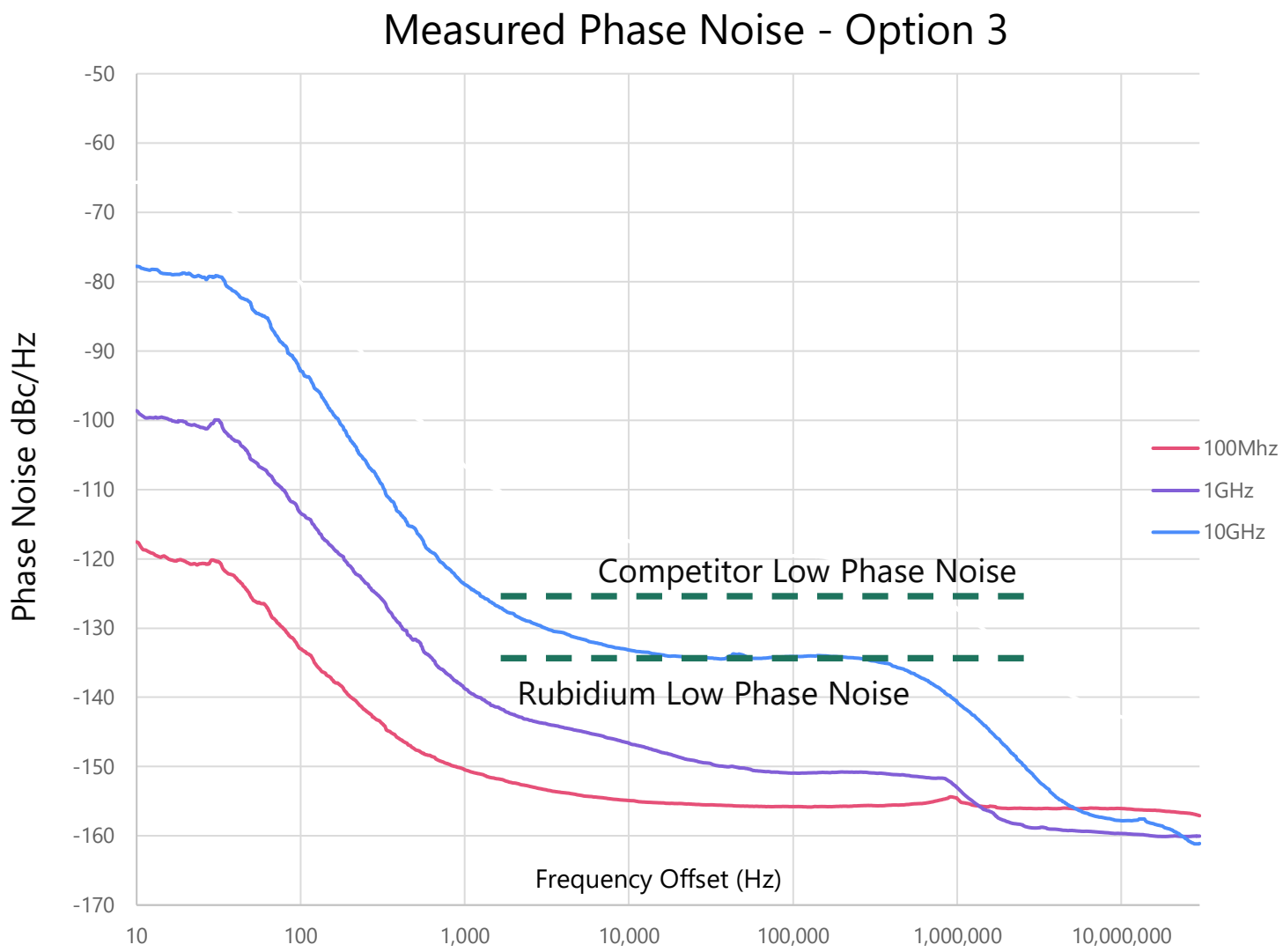
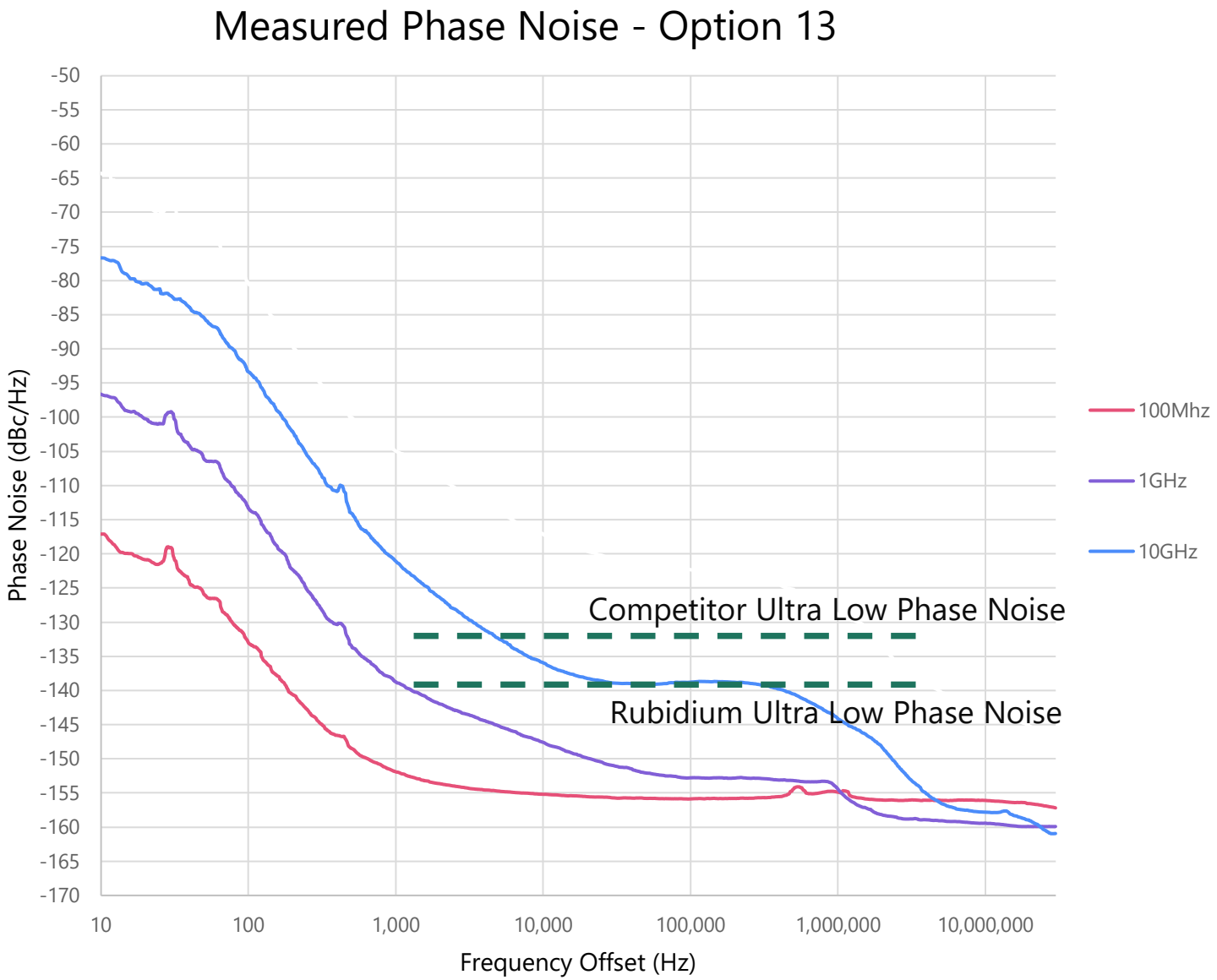
Rubidium™ – Low Phase Noise (meas)



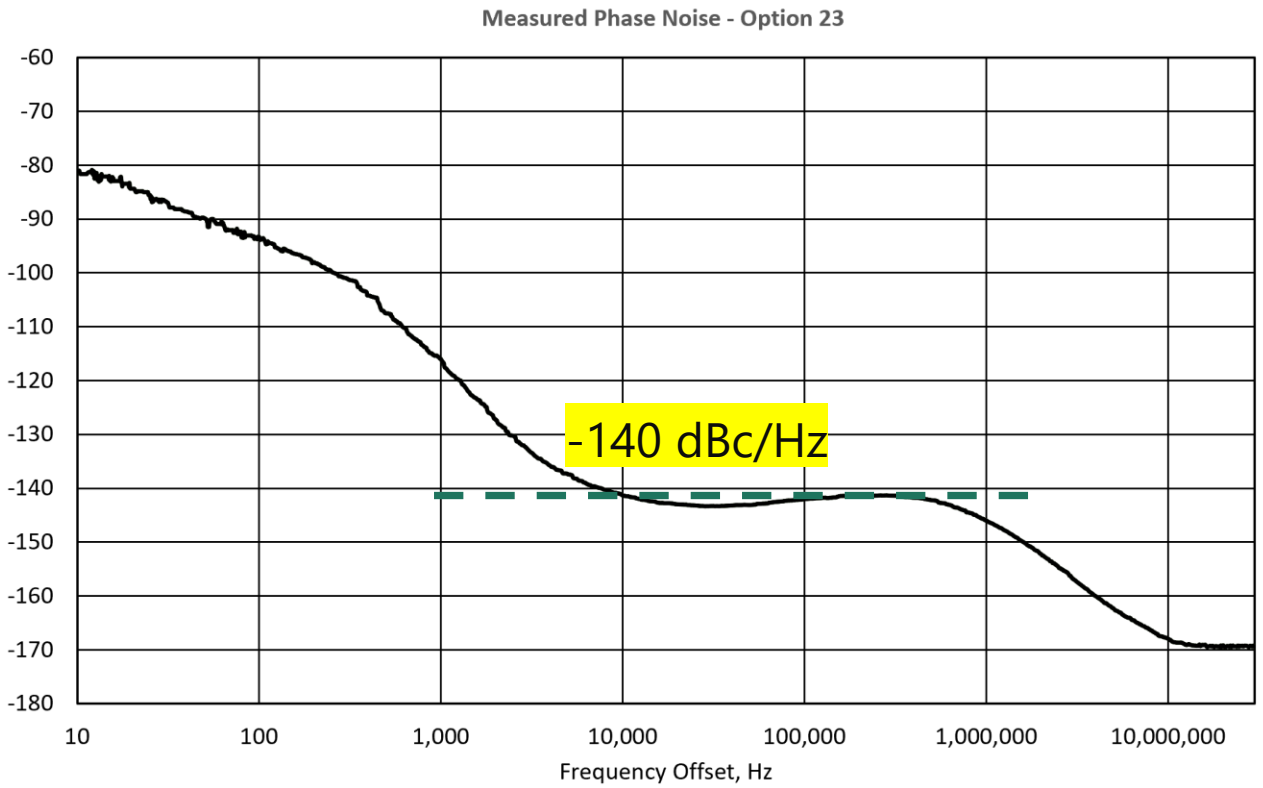
Rubidium™ – Ultra Low Phase Noise (meas)



Rubidium™ - Premium Phase Noise (meas)

Premium Phase Noise, CW (measured)

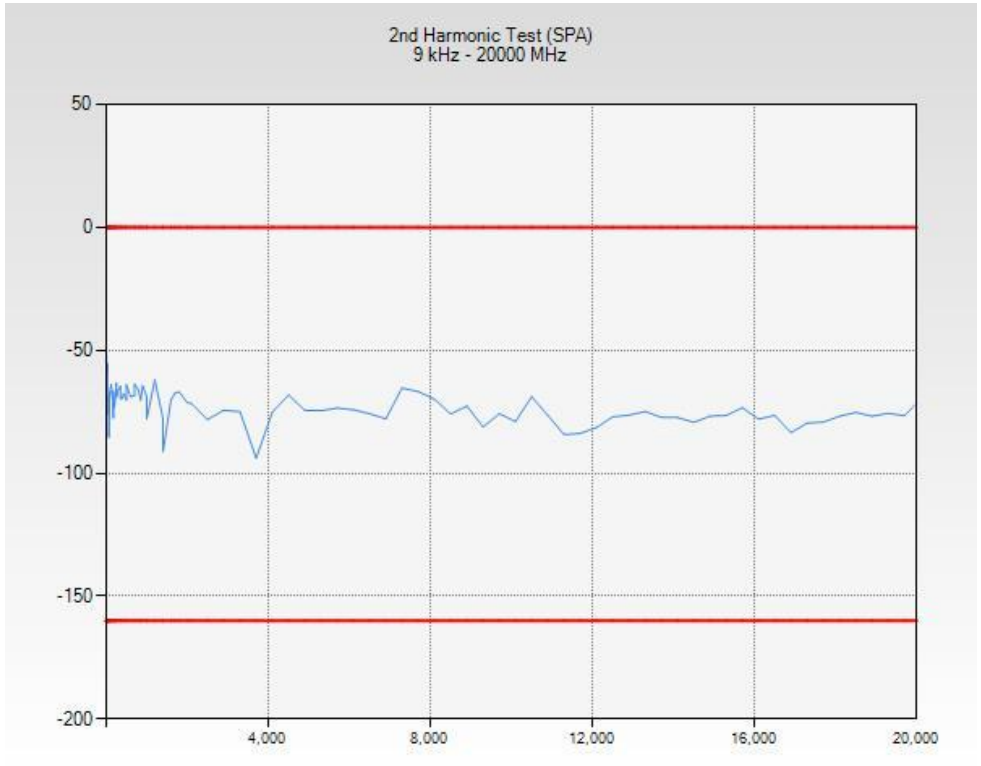
For CW applications, even lower phase noise than the Ultra Low Phase Noise (Option 13) are possible

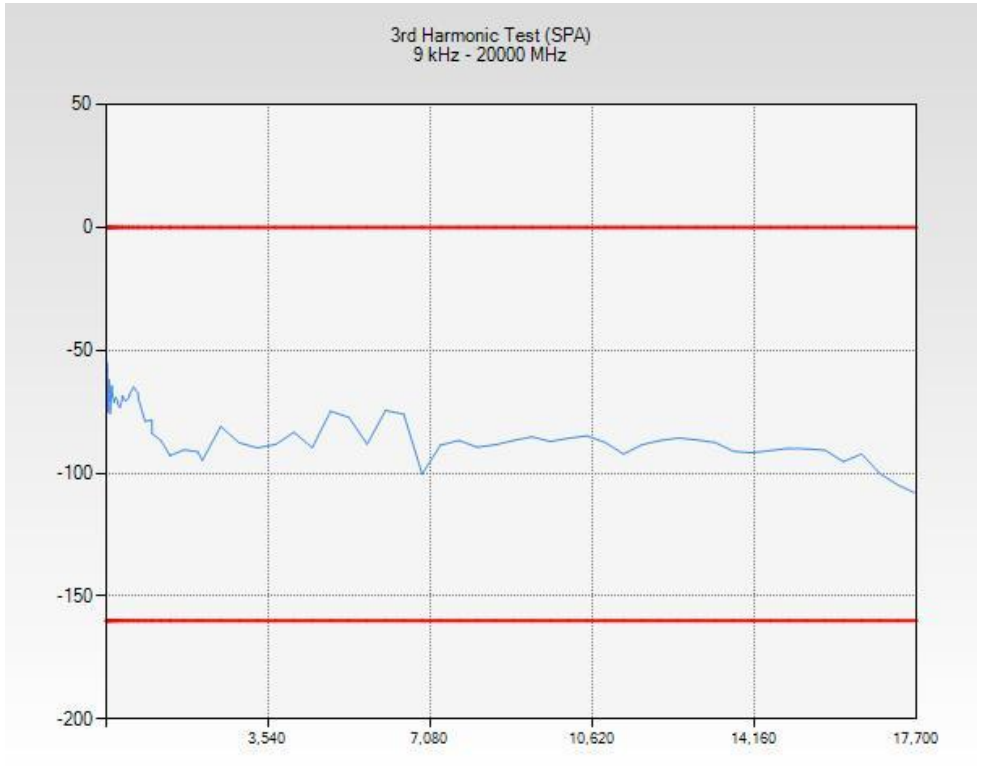


- ✓ *Option 23 output is available on a separate RF port on the back panel*
- ✓ *Achieves -140 dBc/Hz at 10 GHz and 10 kHz offset*
- ✓ *Covers 2 GHz to 20 GHz frequency range, CW only*
- ✓ *Output power > 14 dBm (unleveled)*
- ✓ *Harmonics: < -10 dBc*
- ✓ *Spurious : < -70 dBc*

Rubidium™ - A Benchmark in Signal Purity

Pushing the envelope in signal purity





- Harmonics at standard output power: Less than -58 dBc across 31.25 MHz to 20 GHz

Nearest Competition SMA 100B harmonics spec: -55 dBc across 10 MHz to 20 GHz.

Summary

- ✓*Rubidium™ Signal generator maintains better phase noise with a robust margin between lower and upper integration BW limits*
- ✓*The lower phase noise results in higher SNR*
- ✓*Higher SNR enables higher accuracy in ENOB measurement of ADCs*
- ✓*Higher SNR enables ENOB measurement of higher resolution ADCs*

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