KEYSIGHT

How does the design of the oscilloscope impact PDV measurements?

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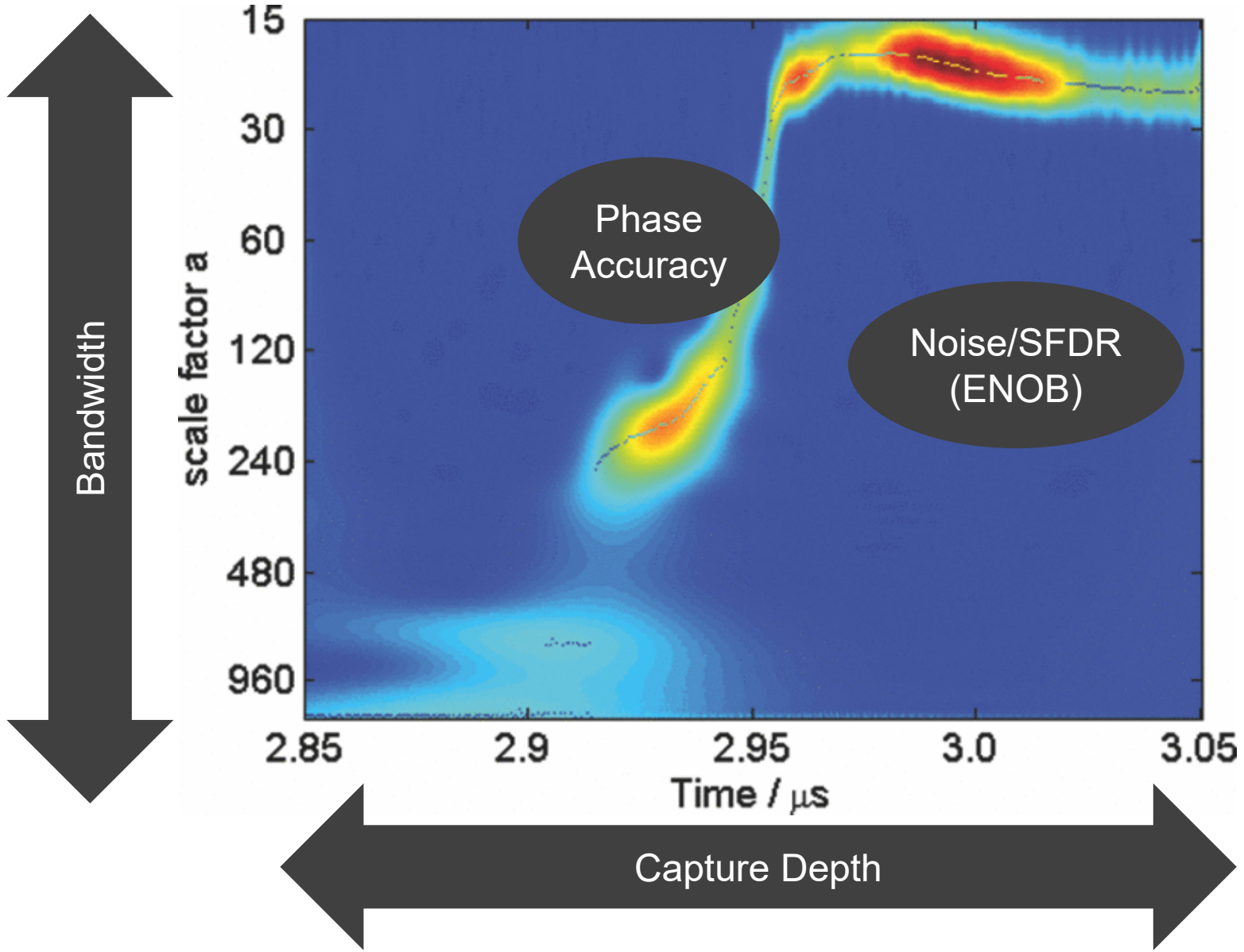
Scope demands for PDV measurement



Agenda

5 minutes	Keys to a low noise front end
5 minutes	ENOB – what it is and isn't
5 minutes	"Dynamic Range" and SFDR – sources and limitations
5 minutes	Optical front ends / questions

Noise Density tells you a lot about a scope architecture.

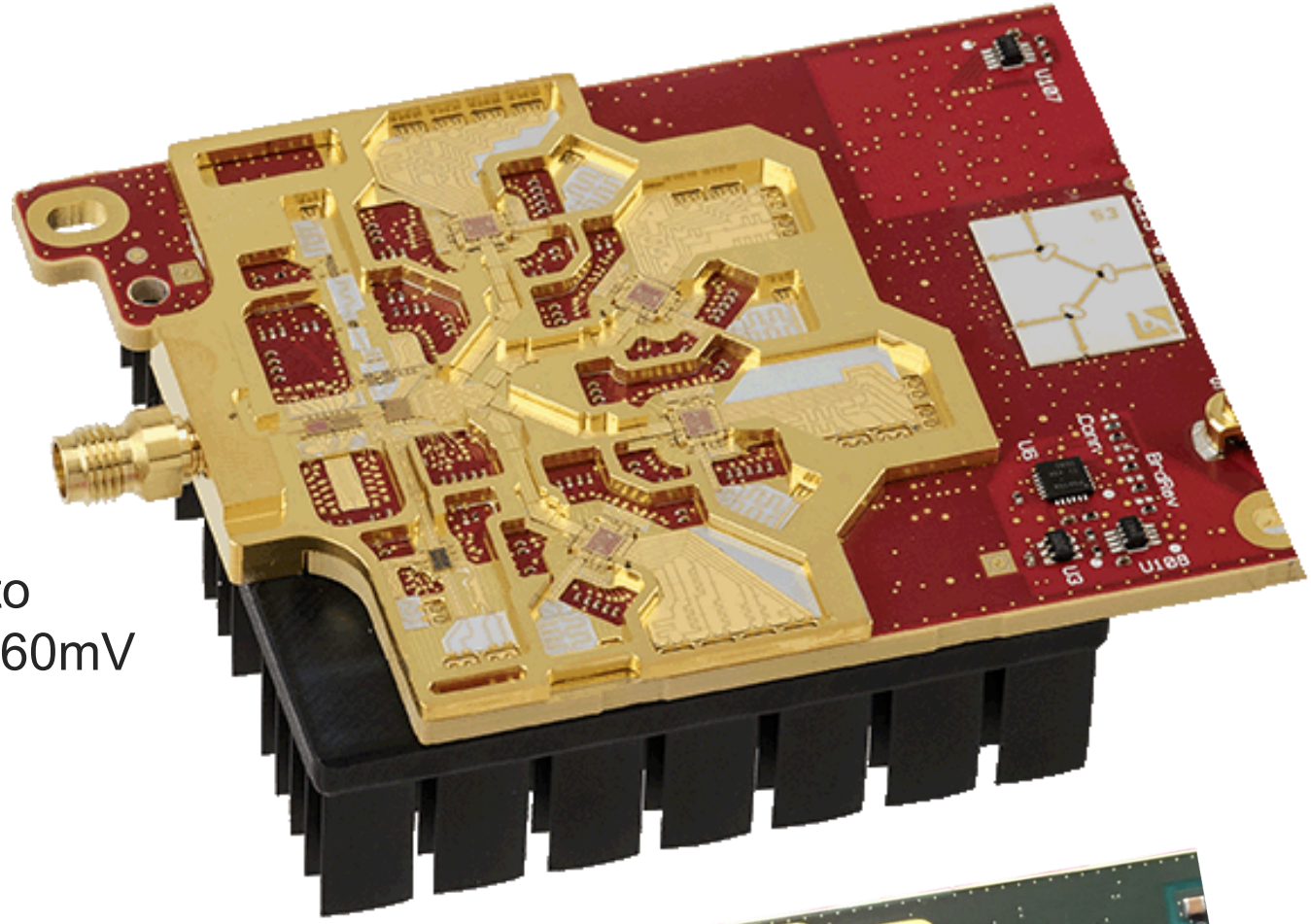
Z-Series
(Older frequency-interleave scope)

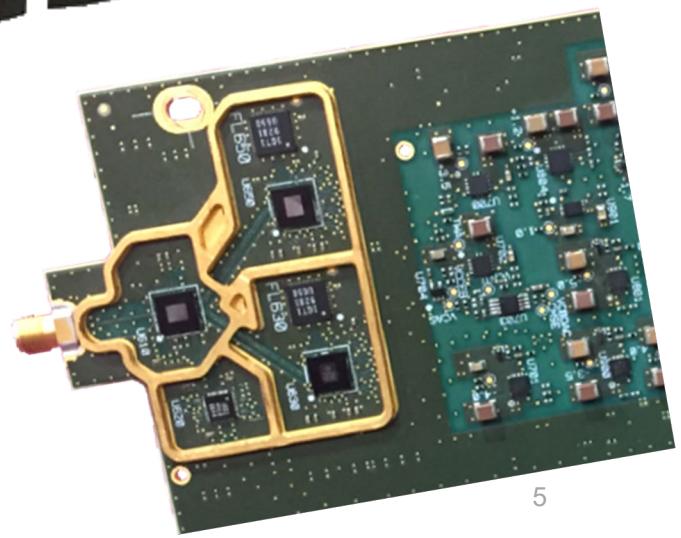
UXR
(Newer time-interleave scope)

UXR has >8dB/Hz better noise density at min V/div

Keys to a low noise front end

- Keep small to avoid loss
  - Front pannel to sampler ~4”.
- Have flexible amplification and attenuation to maximize signal at sampler. 40dB covers ~60mV to 4V full scale.
  - Stepped attenuator (to 20dB)
  - Variable gain preamp (to 20dB)
- Minimize sampler loss – pass as much signal as possible to ADCs
  - Pulse must be narrow to maintain BW.
  - Higher pulse for better SNR
    - InP for fastest. SiGe for middle. CMOS for slowest.





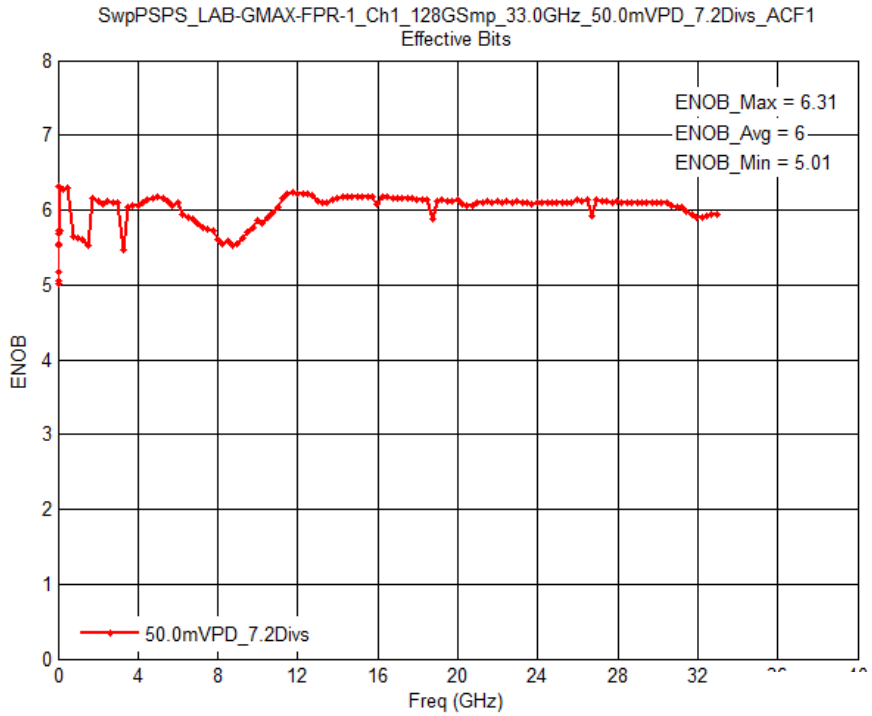
ENOB – Effective Number of Bits

Log2 Expression of Full Scale to Noise and Distortion (measured with 90% FS sine wave).

- Measures relative noise and distortion.
- Is a family of curves, not one number.
  - Curve of ENOB vs. Freq.
  - One curve per v/div setting.
- Is a function of BW.
  - More BW = more noise = less enob.
  - 2x BW = sqrt(2) Noise = - 0.5 ENOB (due to noise).
- Is measured with a sine wave.

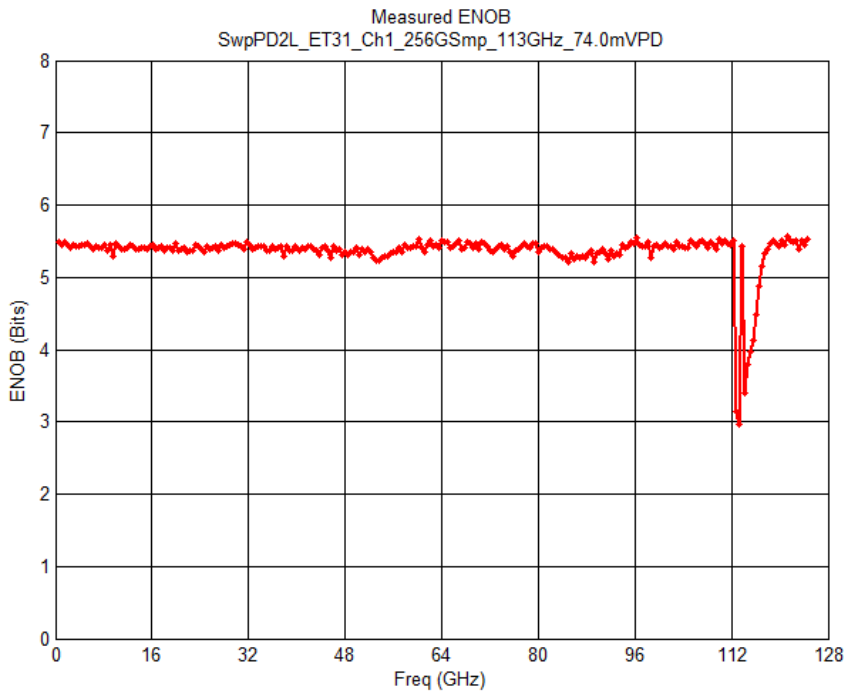
- Does not measure:
  - DC accuracy
  - Magnitude/Phase flatness
  - Intermod (two-tone) distortion
  - SFDR if dominated by noise
  - Distortion at > ½ BW (2nd Harmonic)

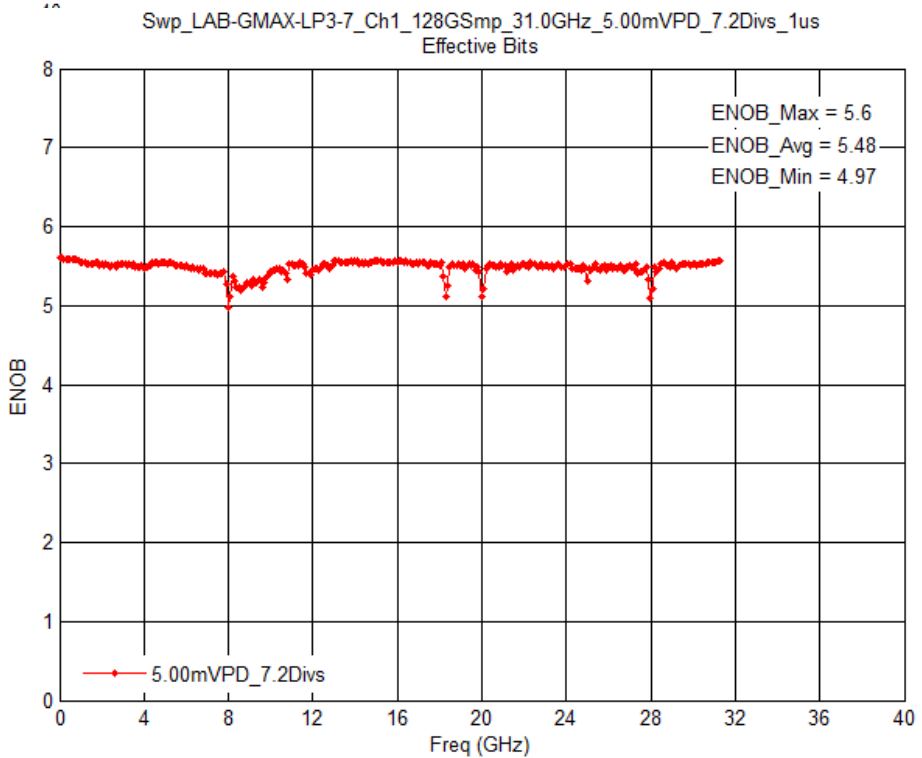
ENOB plots UXR 33 and 110GHz



Higher BW = less ENOB

Smaller signal = less ENOB



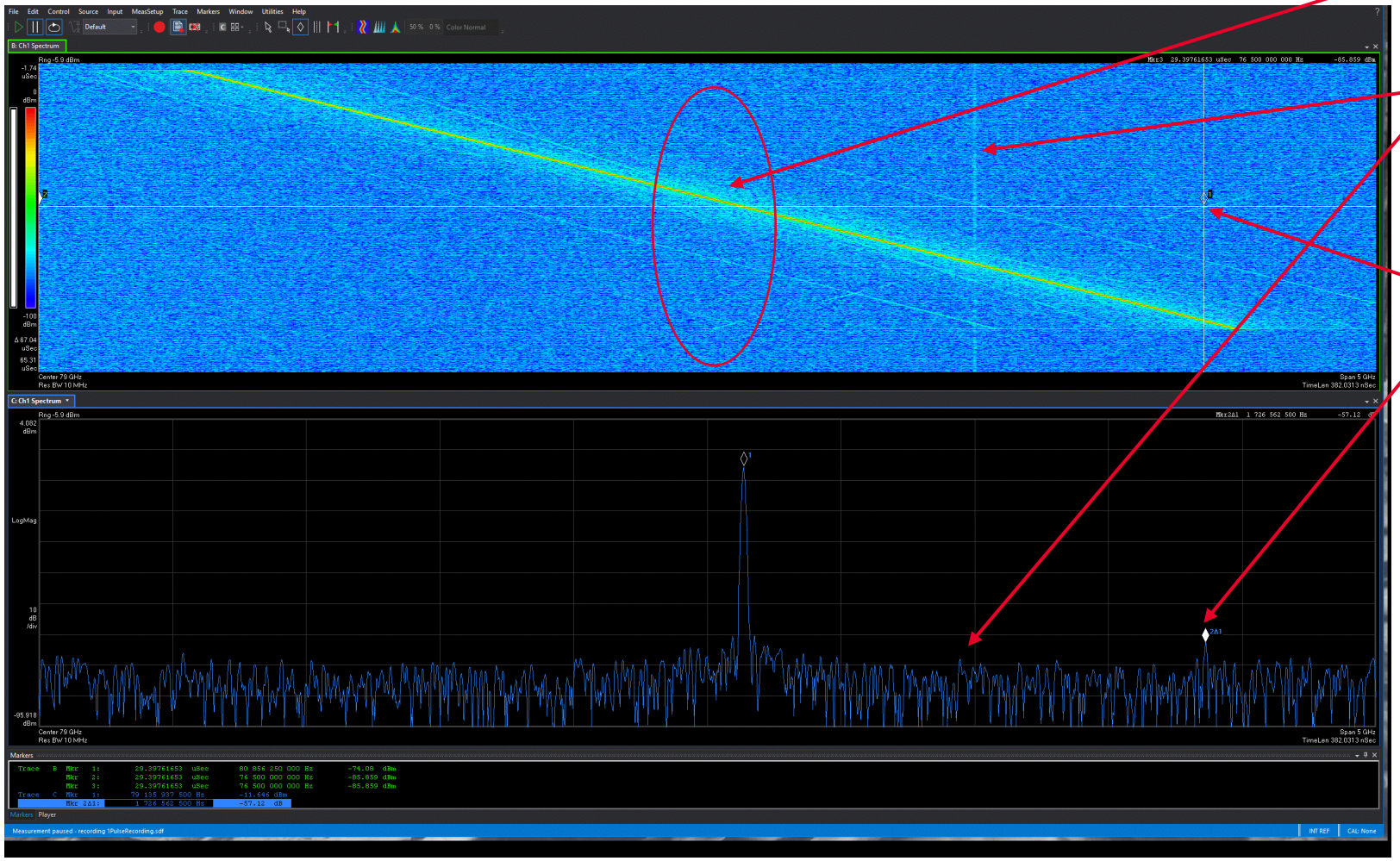


Dynamic Range – Will intermod tones limit measurements?

CF (GHZ)	Ref Level/ Range (dBm)	nomimal PSG power output (each, dBm)	Power left tone (dBm)	Power right tone (dBm)	Power left intermod (dBm)	Power right intermod (dBm)	DANL (dBm/Hz)	left TOI (dBm)	right TOI (dBm)	Min TOI (dBm)	Dynamic Range = 2/3(TOI-DANL) dB
1	6	3	-14	-14	-80.8	-78.7	-140.3	19.4	18.4	**18.4**	105.8
	-20.5	-23	-40	-40.1	-102.9	-102.7	-162.7	-8.6	-8.8	**-8.8**	102.6
2.4	6	3	-14.6	-14.7	-90.5	-86.3	-140.1	23.4	21.1	**21.1**	107.5
5.8	6	3	-15.4	-15.5	-93.2	-78.9	-139.6	23.5	16.2	**16.2**	103.9
12	6	6	-13.6	-13.3	-88.1	-89.4	-138.6	23.7	24.8	**23.7**	108.2
	0	0	-19.7	-19.4	-96.7	-94.5	-144.4	18.8	18.2	**18.2**	108.4
	-6	-6	-25.1	-25.3	-100.5	-99.6	-150.5	12.6	11.9	**11.9**	108.2
	-20.5	-20	-39.1	-39.3	-112.6	-113.1	-161	-2.4	-2.4	**-2.4**	105.7
28	6	8	-15	-13.9	-81.6	-80.9	-136.56	18.3	19.6	**18.3**	103.2
	0	2	-20	-19.9	-86.2	-86.5	-142.4	13.1	13.4	**13.1**	103.7
	-6	-4	-25.8	-25.7	-95.6	-96.4	-148.2	9.1	9.7	**9.1**	104.9
	-20.5	-16	-37.7	-37.7	-116.2	-116.7	-158.8	1.6	1.8	**1.6**	106.9
39	6	10	-13.8	-13.7	-94.6	-94.6	-136.1	26.6	26.8	**26.6**	108.5
	0	4	-19.8	-19.6	-95	-96.9	-141.6	17.8	19.1	**17.8**	106.3
	-6	0	-23.4	-23.3	-93.9	-92.3	-147.9	11.9	11.2	**11.2**	106.1
	-20.5	-14	-37.1	-37.1	-111.1	-110.4	-158.9	-0.1	-0.4	**-0.4**	105.6
50	6	10	-15.9	-16.7	-87.6	-88.7	-137.162	20.0	19.3	**19.3**	104.3
	0	4	-21.8	-22.5	-95.5	-94.9	-142	15.1	13.7	**13.7**	103.8
	-6	0	-25	-26.1	-101	-99.8	-148.69	13.0	10.8	**10.8**	106.3
	-20.5	-14	-39.3	-40	-111.3	-114	-159.5	-3.3	-3.0	**-3.3**	104.1
67	6	14	-15.2	-15	-83	-81.2	-138.6	18.7	18.1	**18.1**	104.5
	0	8	-21	-21.6	-89.5	-90.5	-143.6	13.3	12.9	**12.9**	104.3
	-6	2	-26.6	-26.2	-97.7	-96	-150.1	9.0	8.7	**8.7**	105.9
	-20.5	-12	-40.4	-39.9	-106.1	-104.8	-160.6	-7.6	-7.5	**-7.6**	102.0

- TOI measured >18dBm with 6dB attenuation over a wide frequency range.
- DANL with ~20dB preamp gain ~-160dBm/Hz over a wide frequency range.
- DR in 1Hz BW from 2/3(TOI-DANL) is ~105dB.
- One typically would not make a 1Hz wide measurement with a UXR. If you are making a 1GHz wide measurement with 1MHz RBW, this DR is reduced by ~40dB to ~65dB, which is within the SFDR of the scope in many cases.
- 0.5% EVM = 46dB
- ***Conclusions***
  - ***SFDR and TOI will not limit measurement accuracy for wide BW, in-band measurements.***
  - ***If you are looking for spurs with a 1Hz RBW – you should be using a swept SA.***

An SFDR Example



- LO and AM DUT Spurs
- 80GHz Residual Spur
  ~-70BFS
  (typically measured <-65dBFS)
- Gain related spur. Worst case at image of 74 GHz around 80GHz @86GHz
  ~-57dBc
  (typically measured <-52dBc)
- SFDR is very close to the ~60dB distortion floor of the 10 bit ADC.

Keysight O/Es

Magnitude and Phase Calibrated

N7004A	N7005A
30GHz	60GHz
SMF and MMF	SMF only
S-parameters for various wavelengths automatically utilized	
As low as 5uW rms noise @ 33GHz	As low as 11uW rms noise @ 60GHz

Questions?

KEYSIGHT

Thank you