Measurements in Cross-Channel Timing Stability for Large-Scale Multichannel Experiments

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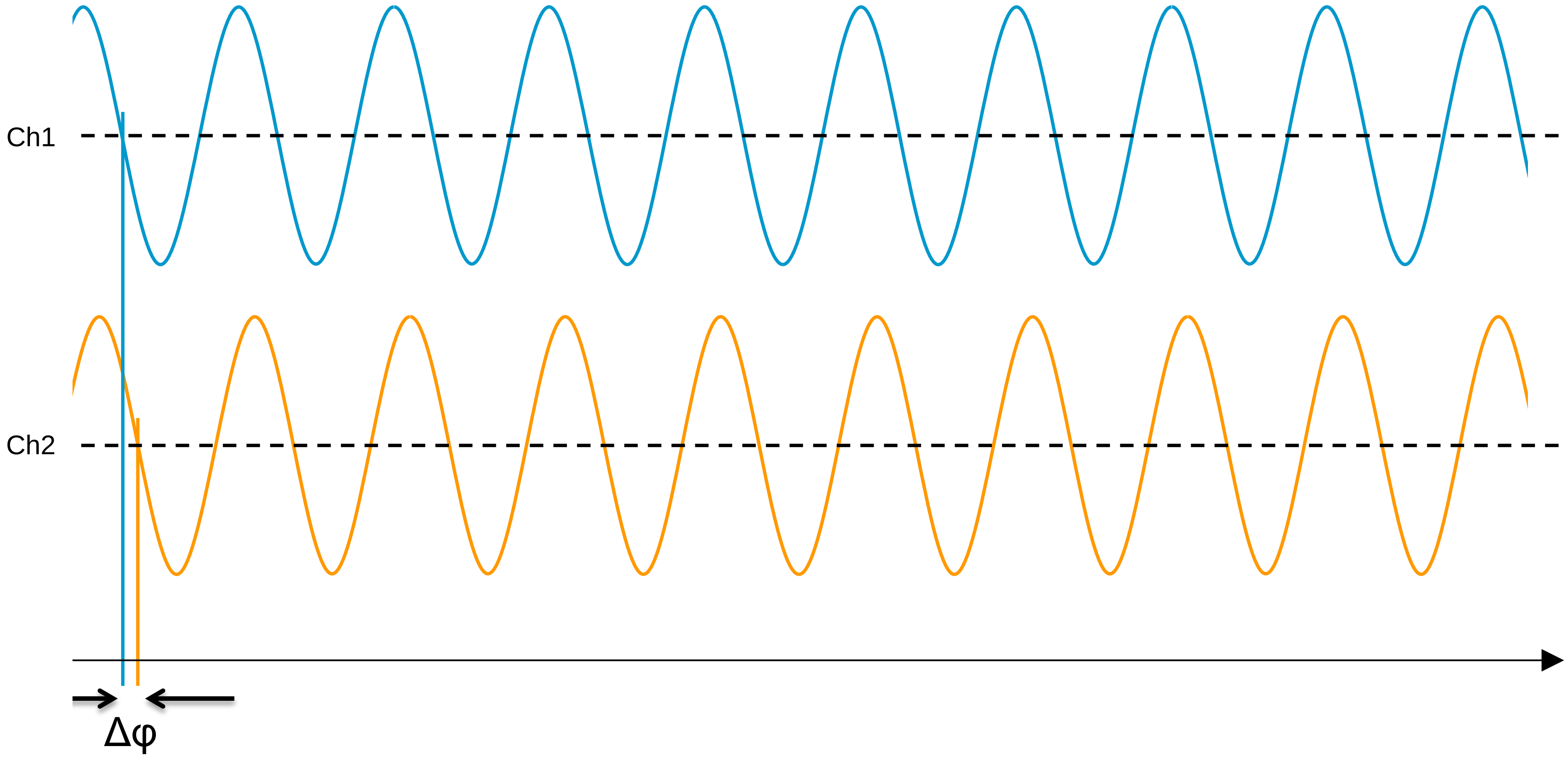
Multichannel applications

Large-scale experiments often require the use of tens or hundreds of synchronized channels of fast high-speed data acquisition to accurately capture experimental events.

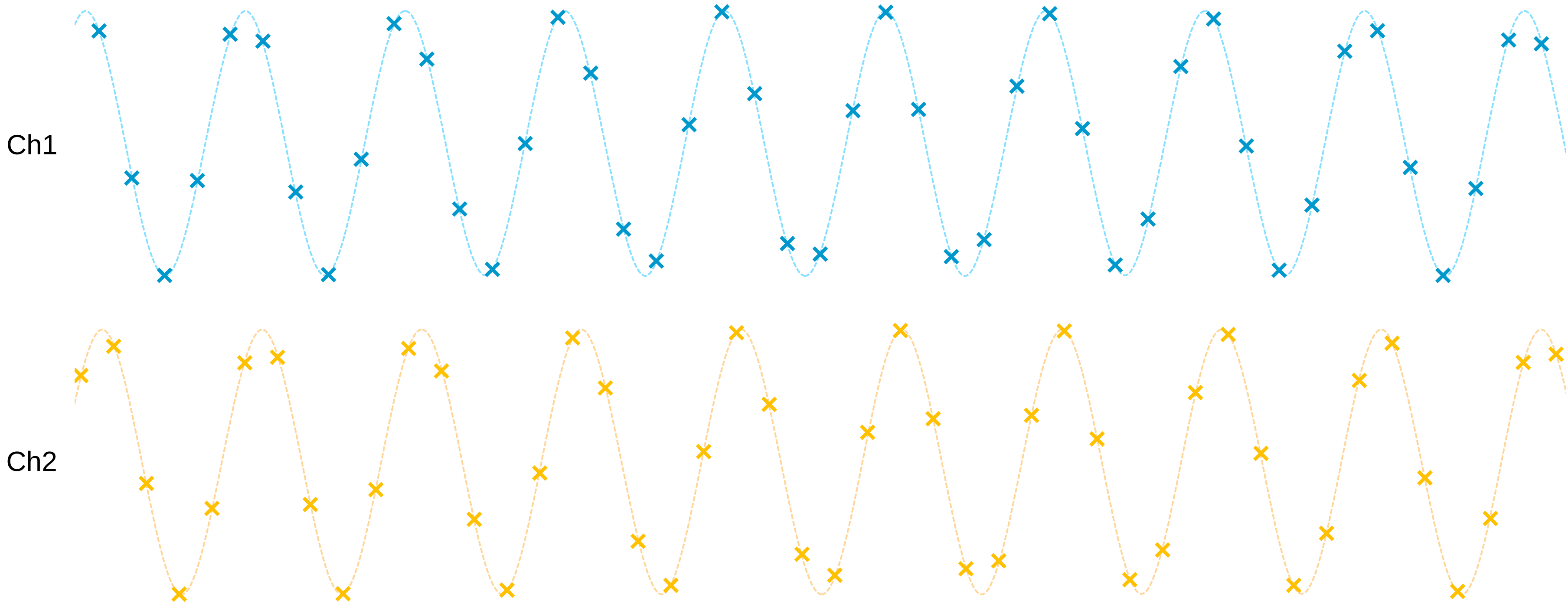
The AXIe platform architecture lends itself for the creation of compact systems with 10's to 100's of channels.

Single tone captured on two independent channels
Fixed phase delta



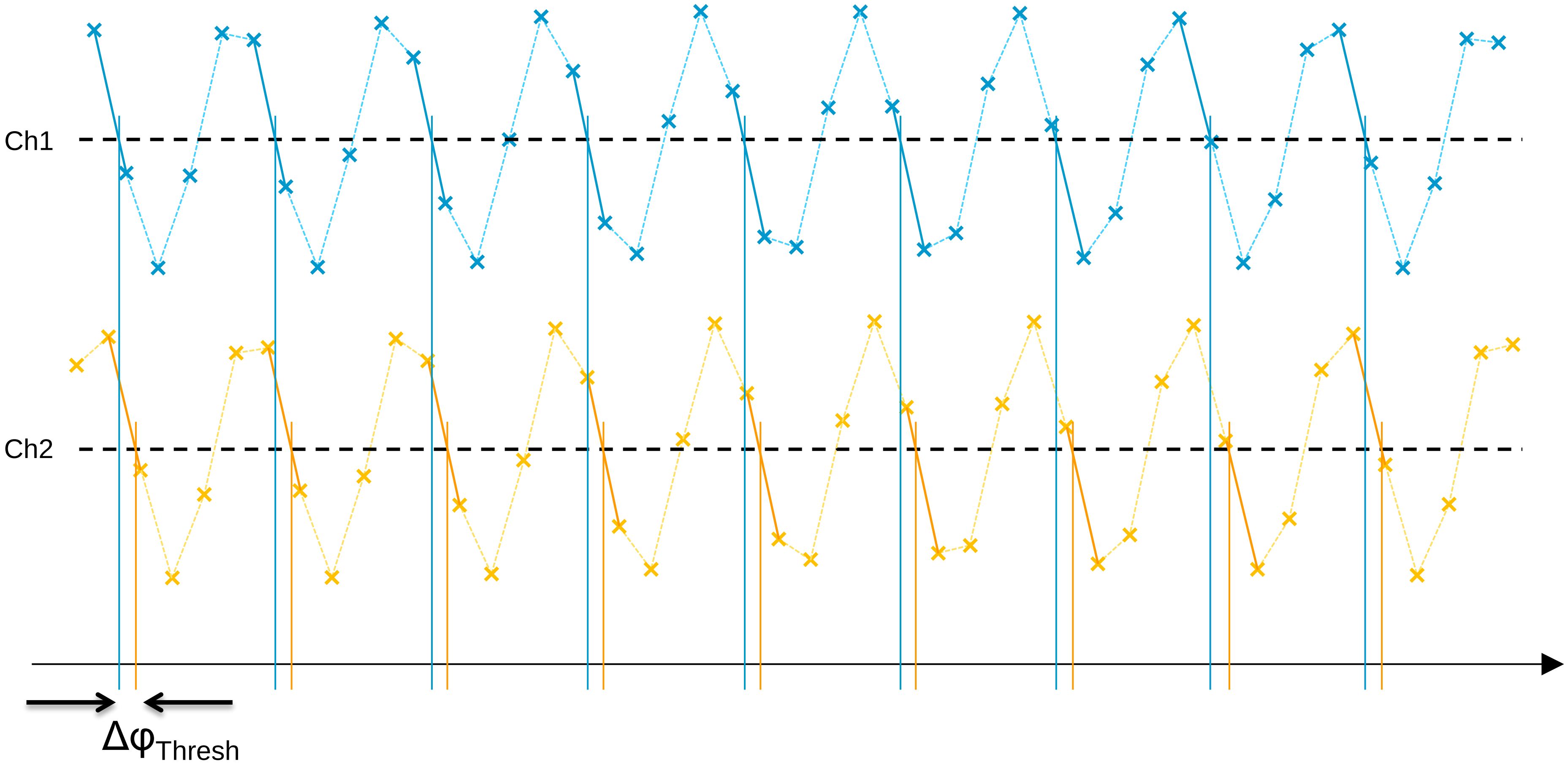
Single tone captured on two independent channels

Discrete sample points on each channel



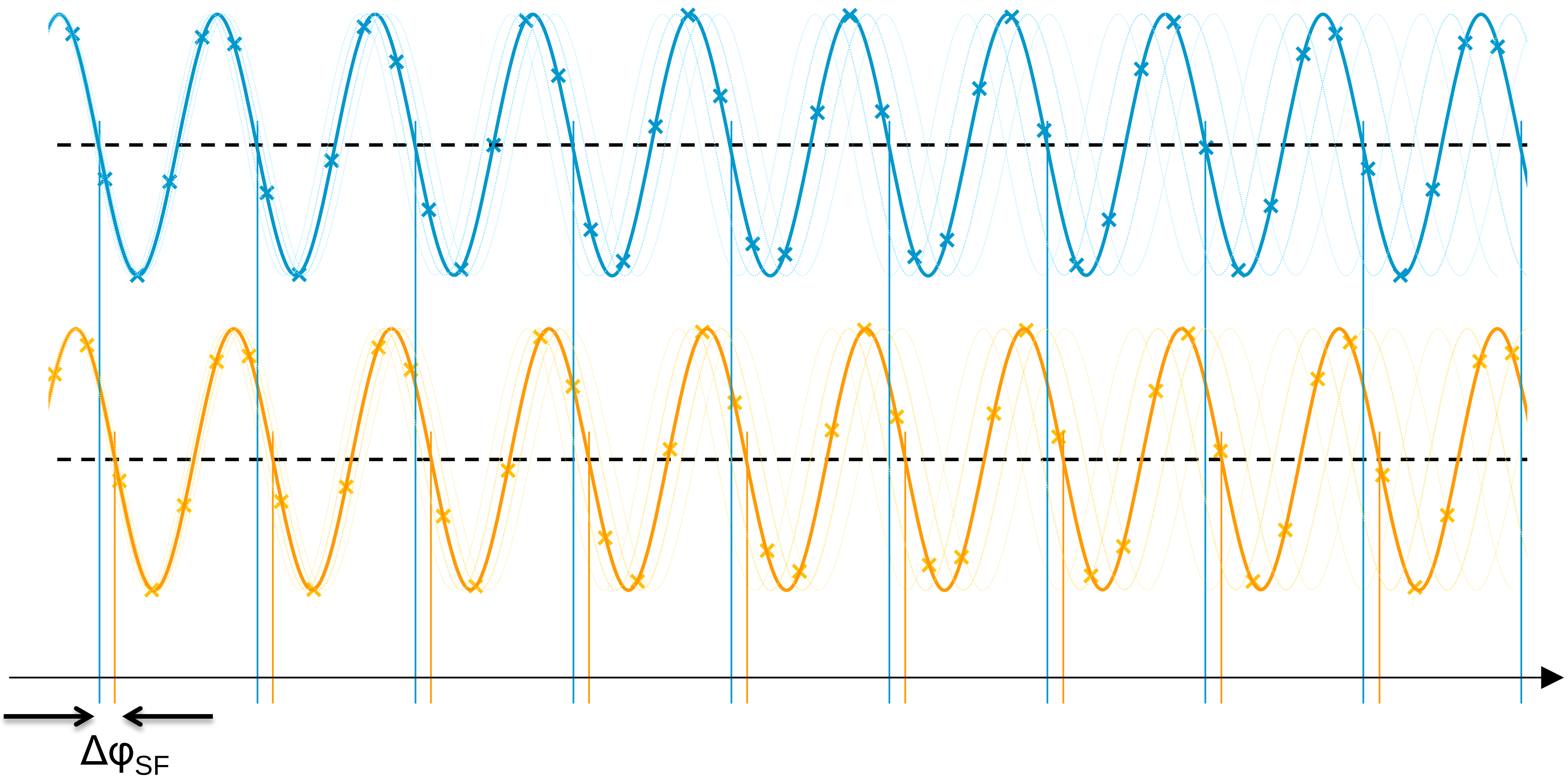
Threshold measurement with linear interpolation

Look for zero crossing points



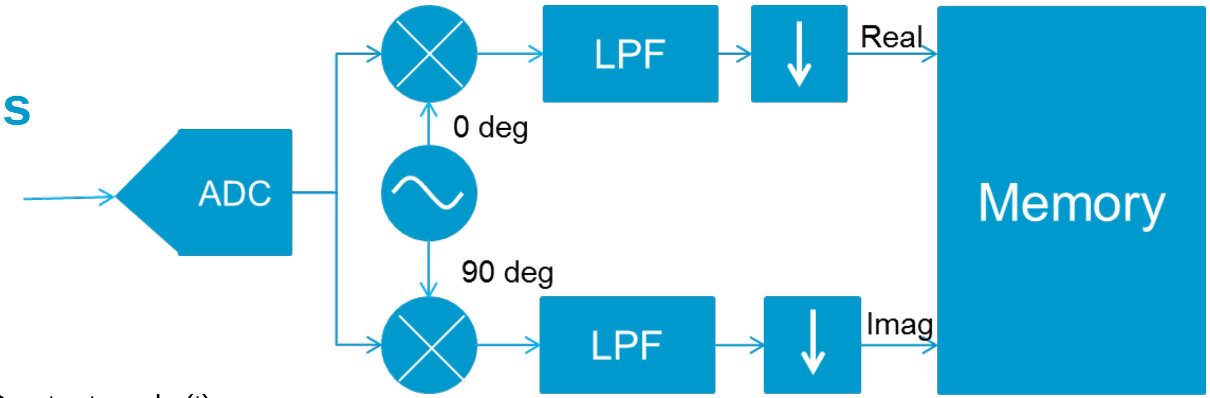
Sinefit method

Best fit of a perfect sinewave to the datapoints



DDC method

Complex IQ calculations



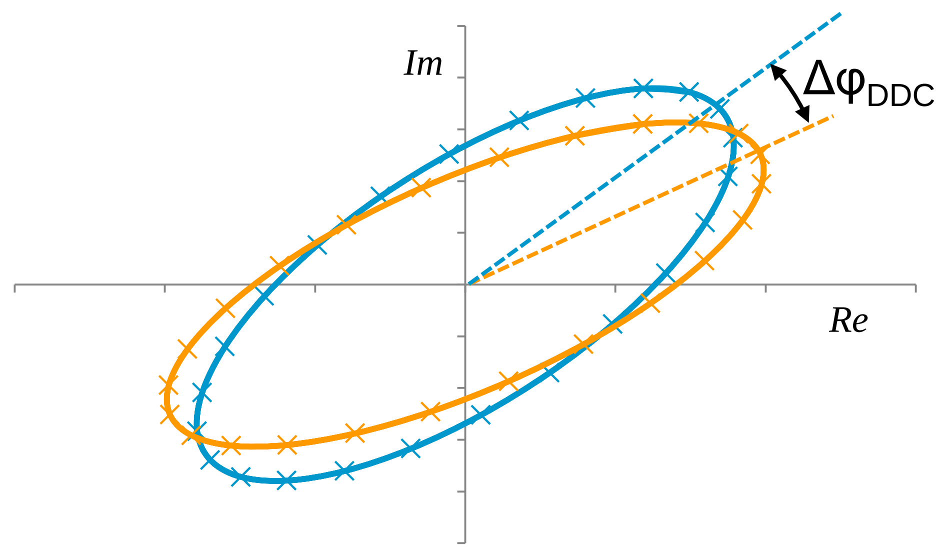
Let r(t) be the reference channel at the DDC output, and x(t) be a signal from another channel.
Let X = [x0 x1 x2 … xn-1] be N complex samples of x(t),
Let R = [r0 r1 r2 … rn-1] be N complex samples of r(t).
In complex number G1 that represents the cross-channel response is:

$$G1 = \frac{\sum_{n=0}^{N-1} x(nT) * r(nT)^*}{\sum_{n=0}^{N-1} r(nT) * r(nT)^*}$$

$$G1 = \frac{XR'}{RR'}$$

where R’ is the conjugate transpose of R. The cross channel phase is then:

$$\Delta\varphi_{rad} = atan2(Im\{G1\}, Re\{G1\})$$



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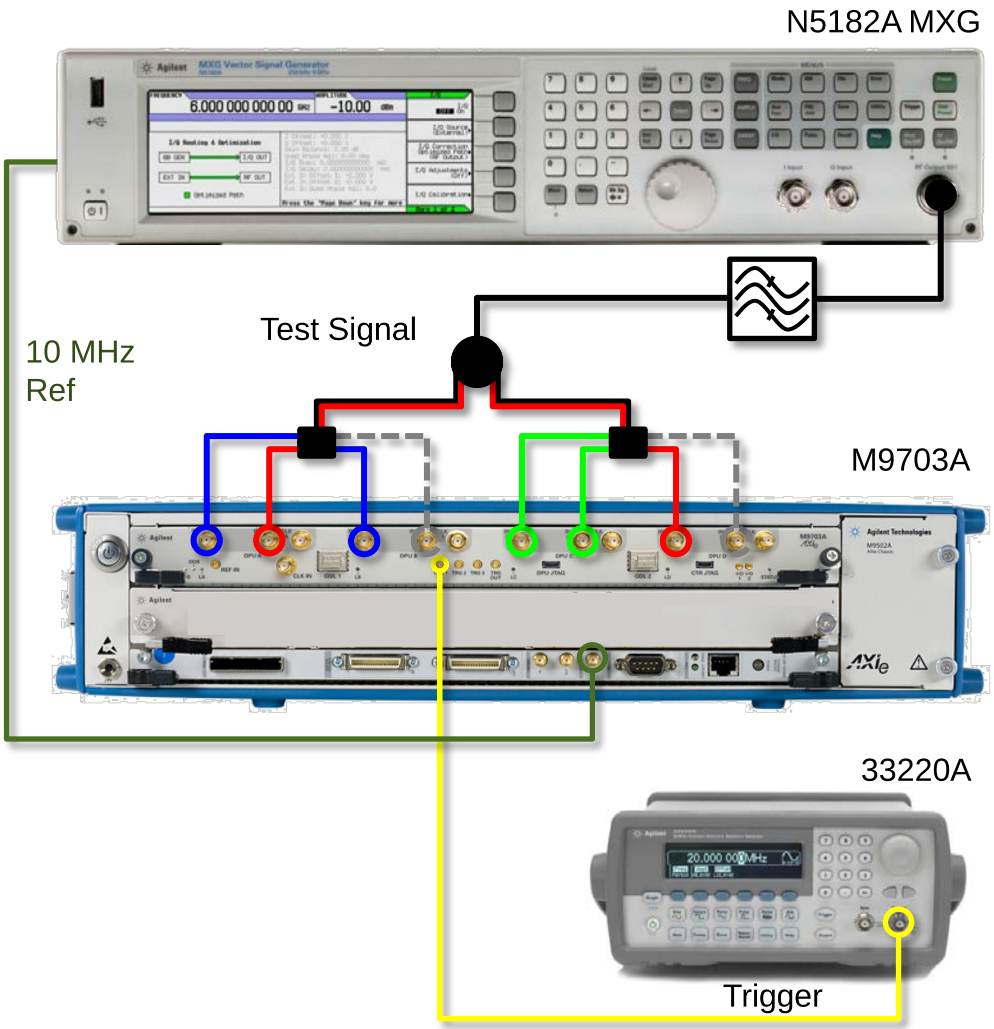
Comparison of methods

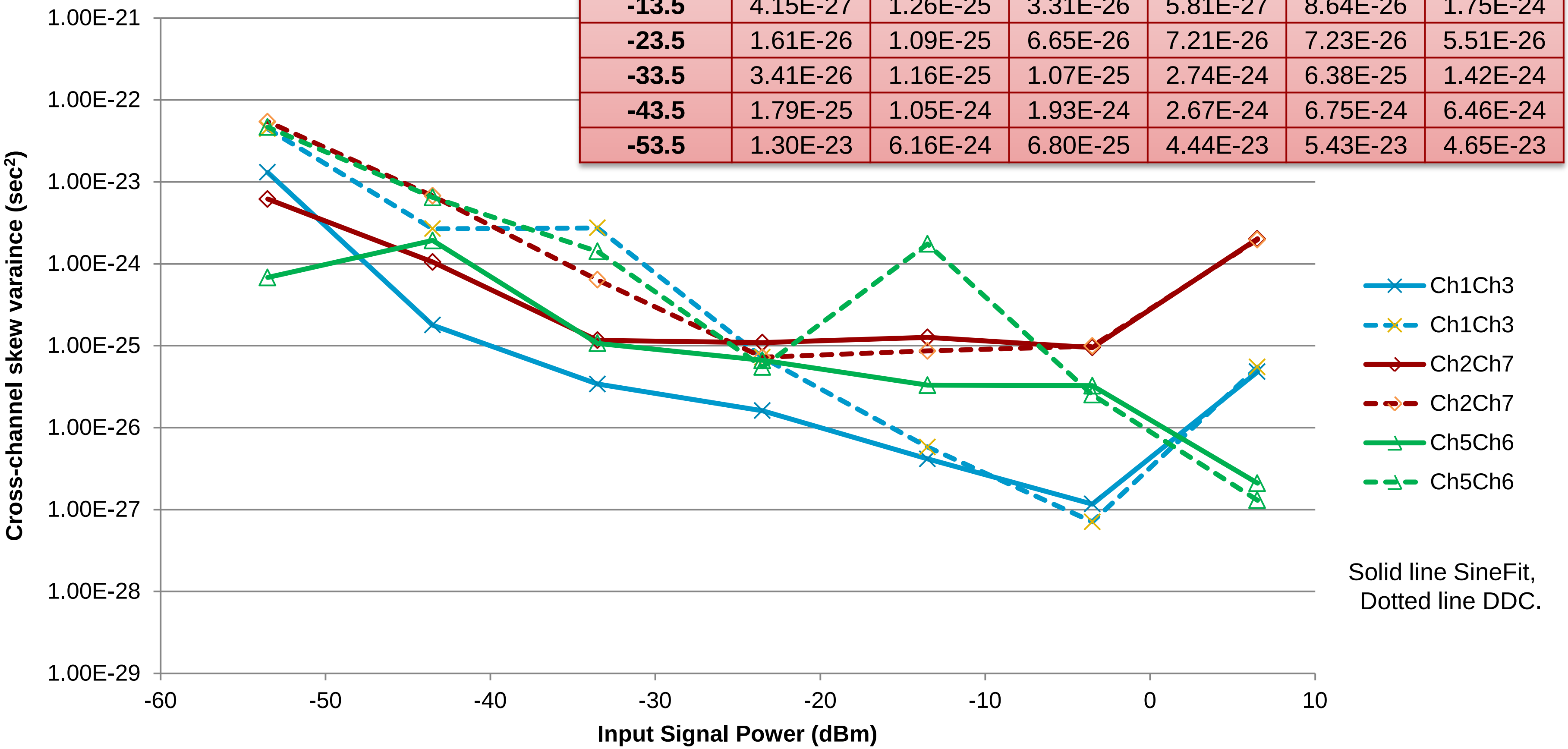
- $\Delta\varphi_{Thresh}$
  - Susceptable to jitter and linear interpolation errors, as well as dc offset of the signal.
  - Fast, driver-based measurement.
- $\Delta\varphi_{SF}$
  - Estimation method, best used with a prime number of complete signal periods in the acquisition.
  - Can be used to fit frequencies above Nyquist
  - Slow, iterative calculation-based fitting
- $\Delta\varphi_{DDC}$
  - Limited to frequencies below Nyquist
  - Multiple measurements within a single acquisition
  - Relatively fast calculation.

Experimental Setup



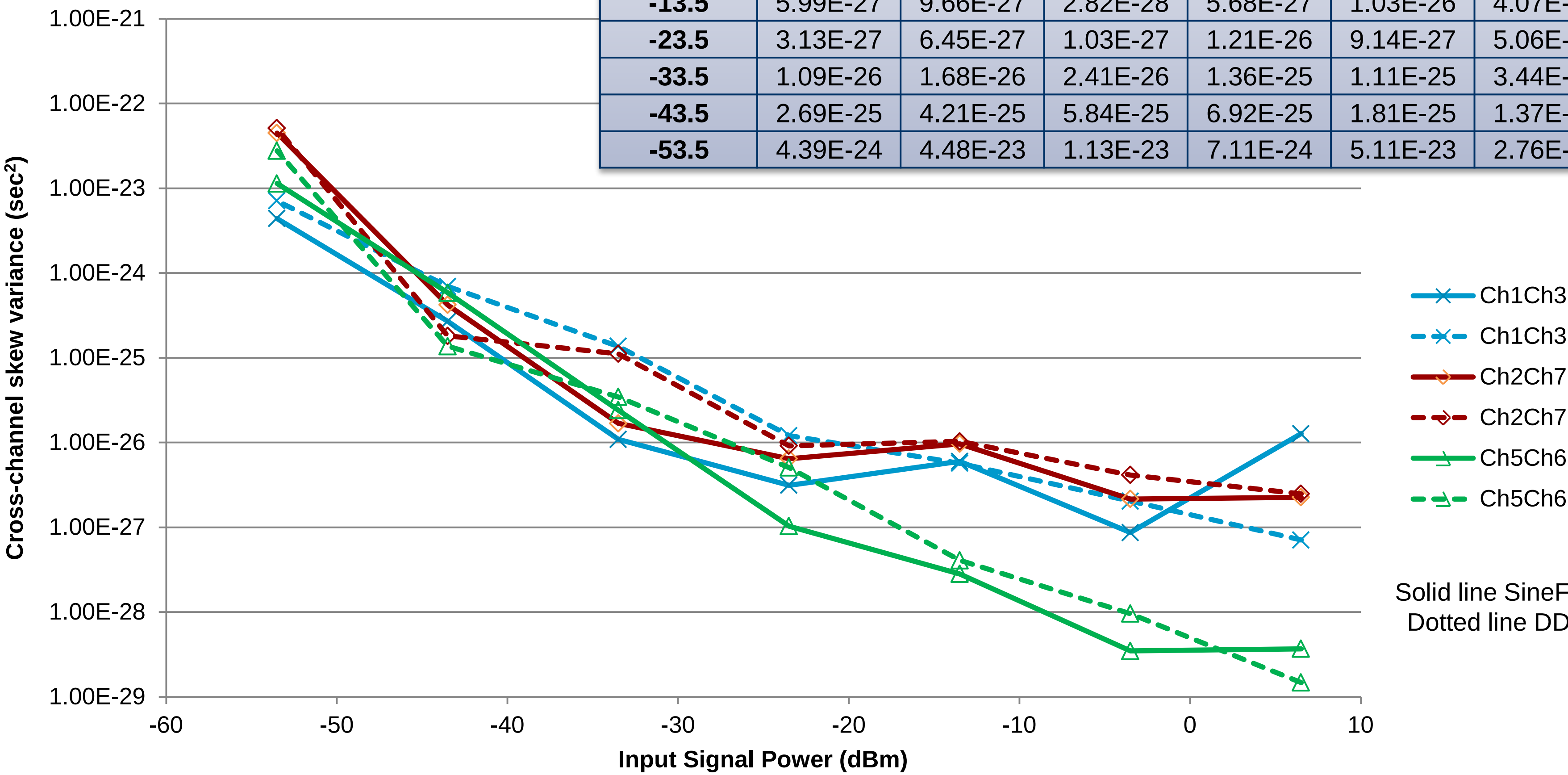
Skew variance plotted as a function of input signal power, at 100 MHz

	Sinefit Method			DDC Method		
Input Power (dBm)	Skew Variance (sec²) Ch1Ch3	Skew Variance (sec²) Ch2Ch7	Skew Variance (sec²) Ch5Ch6	Skew Variance (sec²) Ch1Ch3	Skew Variance (sec²) Ch2Ch7	Skew Variance (sec²) Ch5Ch6
6.5	4.81E-26	2.02E-24	2.10E-27	5.49E-26	1.97E-24	1.30E-27
-3.5	1.17E-27	9.54E-26	3.25E-26	7.07E-28	9.90E-26	2.53E-26
-13.5	4.15E-27	1.26E-25	3.31E-26	5.81E-27	8.64E-26	1.75E-24
-23.5	1.61E-26	1.09E-25	6.65E-26	7.21E-26	7.23E-26	5.51E-26
-33.5	3.41E-26	1.16E-25	1.07E-25	2.74E-24	6.38E-25	1.42E-24
-43.5	1.79E-25	1.05E-24	1.93E-24	2.67E-24	6.75E-24	6.46E-24
-53.5	1.30E-23	6.16E-24	6.80E-25	4.44E-23	5.43E-23	4.65E-23



Skew variance plotted as a function of input signal power, at 300 MHz

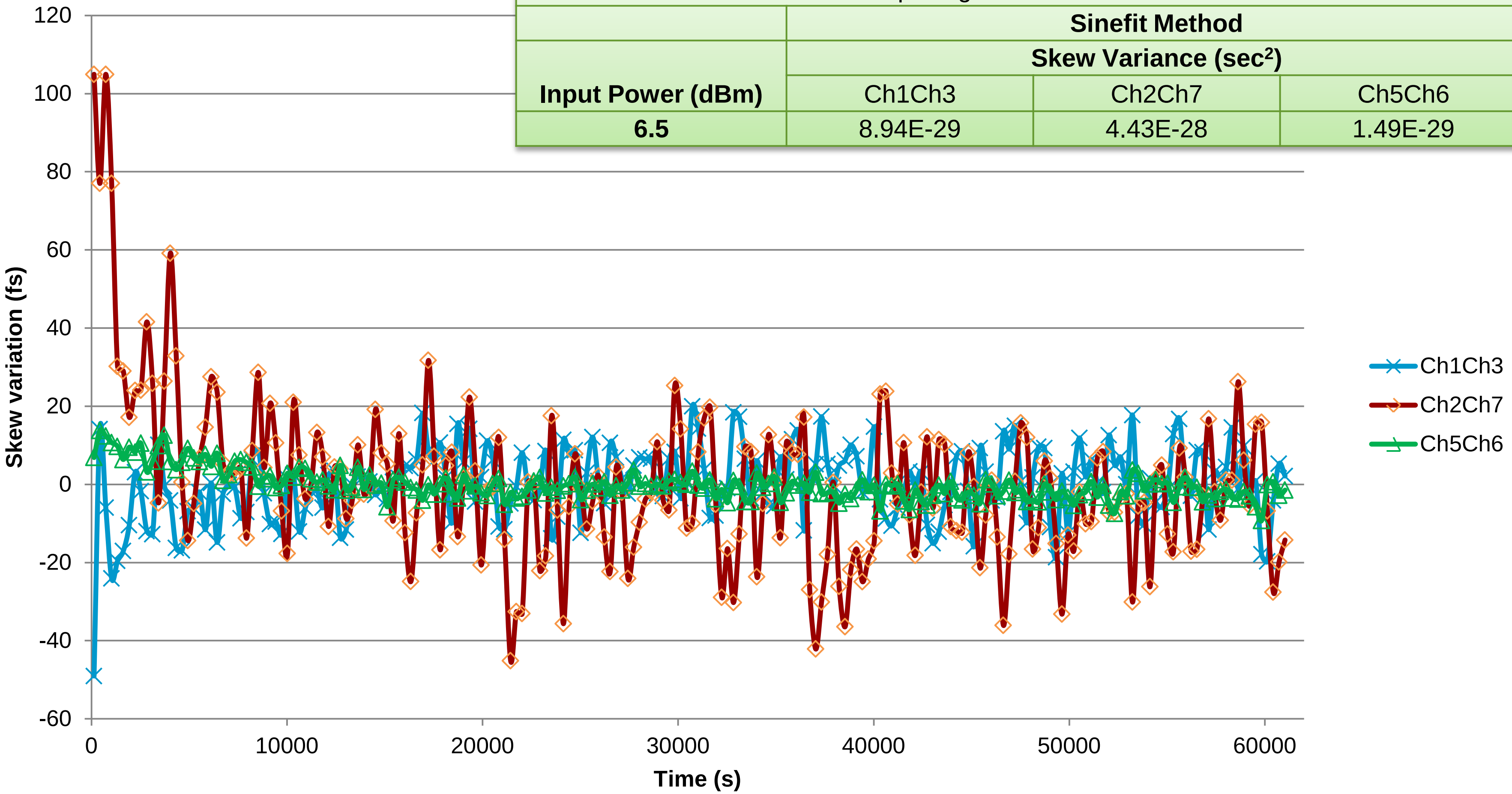
Input Power (dBm)	Sinefit Method Skew Variance (sec^2)			DDC Method Skew Variance (sec^2)		
	Ch1Ch3	Ch2Ch7	Ch5Ch6	Ch1Ch3	Ch2Ch7	Ch5Ch6
6.5	1.27E-26	2.26E-27	3.68E-29	7.07E-28	2.48E-27	1.47E-29
-3.5	8.65E-28	2.15E-27	3.47E-29	2.04E-27	4.13E-27	9.56E-29
-13.5	5.99E-27	9.66E-27	2.82E-28	5.68E-27	1.03E-26	4.07E-28
-23.5	3.13E-27	6.45E-27	1.03E-27	1.21E-26	9.14E-27	5.06E-27
-33.5	1.09E-26	1.68E-26	2.41E-26	1.36E-25	1.11E-25	3.44E-26
-43.5	2.69E-25	4.21E-25	5.84E-25	6.92E-25	1.81E-25	1.37E-25
-53.5	4.39E-24	4.48E-23	1.13E-23	7.11E-24	5.11E-23	2.76E-23



Solid line SineFit, Dotted line DDC.

Skew variation from the average level, as a function of time, at 300 MHz

Skew variance for a 300 MHz input signal for 204 measurements taken over 17 hours.			
	Sinefit Method		
Input Power (dBm)	**Skew Variance (sec²)**		
	Ch1Ch3	Ch2Ch7	Ch5Ch6
6.5	8.94E-29	4.43E-28	1.49E-29



Conclusions

We have shown the incredible performance available today for synchronous multichannel acquisition from commercially available digitizers.

These measurements were made with careful choice made for the cabling, because at a system level the skew will depend not only on the path lengths carrying the input signal within the digitizer component, but also the path lengths leading up to the digitizer.

Questions?