Application Brief

Allan Deviation Measurement Data From LMX2615 and LMX2624

Narala Reddy

Introduction

This application brief shows the silicon results of Allan deviation measured using FSWP50 at the LMX2615 and LMX2624 output with two different input reference sources. Power law dependence in the spectral content of oscillators is a known phenomenon. Classical variance can diverge or become unreliable for these noise processes when dealing with flicker and frequency random walks. To address this issue, Allan variance is introduced. Allan deviation (2-sample deviation) is the square root of Allan variance, which is a standard method for describing the short-term stability of oscillators in time domain. Allan deviation is used to measure the stability of oscillators due to noise processes not that of systematic errors or temperature effects. Allan deviation is the measurement showing instability in the frequency on the y-axis for various time intervals on the x-axis. For a proper measure of random frequency fluctuations at longer measurement time intervals, aging from oscillators (reference source) must be subtracted. Allan deviation plots can be used for comparing different reference oscillators and used to select the preferred oscillator (low noise). Allan deviation is used in applications in various fields such as meteorology, atomic clocks, and so on. For an oscillator of 100MHz, an Allan deviation of 1×10^{-11} for an observation window of one second can be seen as frequency variation in terms of the RMS is $1 \times 10^{-11} \times$ 100MHz, which is 10^{-3} (1mHz). Any random samples taken within a window of one second has a frequency RMS variation of 1mHz.

Allan Deviation Measurement Options

There are multiple ways to measure the Allan deviation in time and frequency domain. One such approach in time domain is a frequency counter-based approach. Accuracy depends on the resolution of the frequency counter and memory that is required when measurement time increases. Another approach is the frequency domain approach, where phase noise data is used to derive the Allan deviation.

One such quick approach is available in R&S FSWP50. This feature measures the Allan deviation using the information from Phase noise analyzer. R&S claim that FSWP50 can be used for measuring till 10^3 seconds by extending the phase noise observation window down to 1mHz.

There are multiple regions in the Allan deviation plot with respect to time. Those are white phase region, Flicker phase regions, white frequency regions, flicker frequency regions, and random walk frequency regions. These regions are shown in Figure 1.

There are some limitations in measuring the Allan deviation with R&S FSWP50 as shown in Table 1.

Table 1. Allan Deviation FSWP-50 Specifications

	Allan Deviation	Allan Variation
Frequency range	R&S®FSWP8	1MHz to 8GHz
	R&S®FSWP26	1MHz to 18GHz
	R&S®FSWP50	1MHz to 50GHz
Measurement range	Tau	100ns to 1 000 000s

Table 1. Allan Deviation FSWP-50 Specifications (continued)

	Allan Deviation	Allan Variation
Allan deviation	Reference frequency internal and with R&S®FSWP-B61 option	1.0×10^{-13} at Tau = 1s (nom.)
		1.1×10^{-11} at Tau = 1000s (nom.)
	Reference frequency with highly stable external reference, reference loop bandwidth 100Hz	8.8×10^{-14} at Tau = 1s (nom.)
		7.0×10^{-15} at Tau = 1000s (nom.)

With B61 option, $1*10^{-13}$ at Tau=1sec can only be measured. To measure lower than that, external reference must be used. Depending on the reference source used for the LMX2615 and LMX2614, external source phase noise requirements depends.

Allan Deviation Measurement Data

In this application brief, two difference reference sources are used for evaluating the Allan deviation at the output of LMX2615 and LMX2624. Silicon results for the cases in Table 2 are shown in this application brief.

Table 2. Reference Source and Output Frequency

Case	Reference Source	Output Frequency and Device
1	SMA100B, 100MHz	8GHz, LMX2615
2	Wenzel, 100MHz	8GHz, LMX2615
3	SMA100B, 100MHz	8GHz, LMX2624
4	Wenzel, 100MHz	8GHz, LMX2624

Case 1: LMX2615 at 8GHz Output, SMA100B 100MHz Reference

Figure 1 shows the Allan deviation and Allan variance for the input reference source of 100MHz and at the 8GHz output of LMX2615. Flicker frequency floor depends on the type of reference used and PLL noise. The flicker floor is close to 300ms time interval in the reference and is followed at the output of 8GHz.

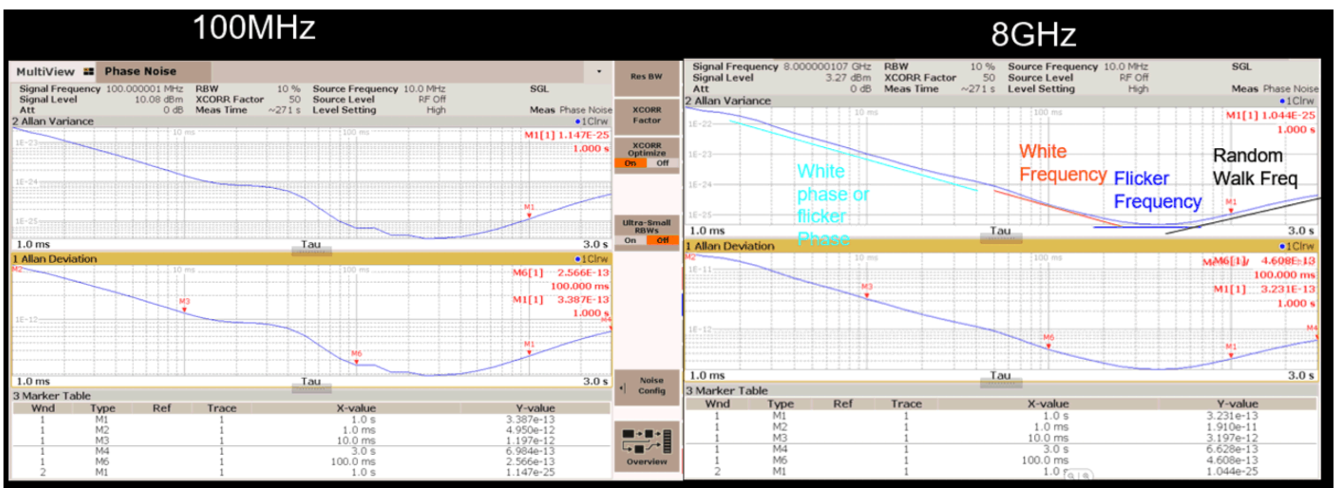

Figure 1. LMX2615 at 8GHz Output, SMA100B 100MHz Reference

Case 2: LMX2615 at 8GHz Output, Wenzel 100MHz Reference

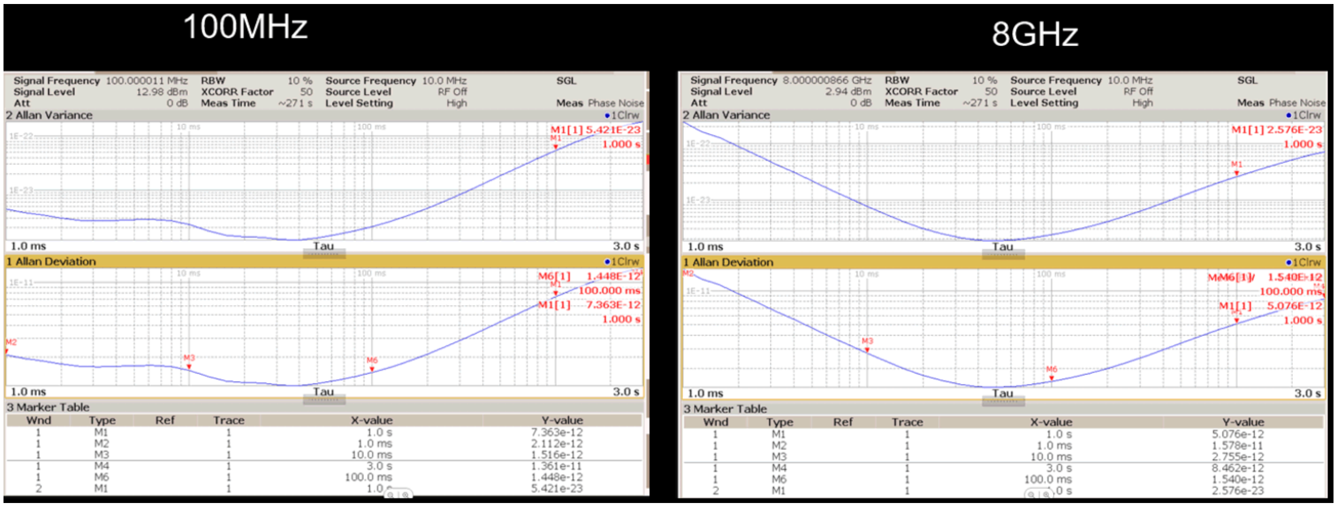

Figure 2. LMX2615 at 8GHz Output, Wenzel 100MHz Reference

- Wenzel source has degraded 1sec and 3sec numbers compared to the SMA100B source, which is propagated to 8GHz output.

Reference source plays a crucial role for the Allan deviation at the output of LMX2615.

Case 3: LMX2624 at 8GHz Output, SMA100B 100MHz Reference

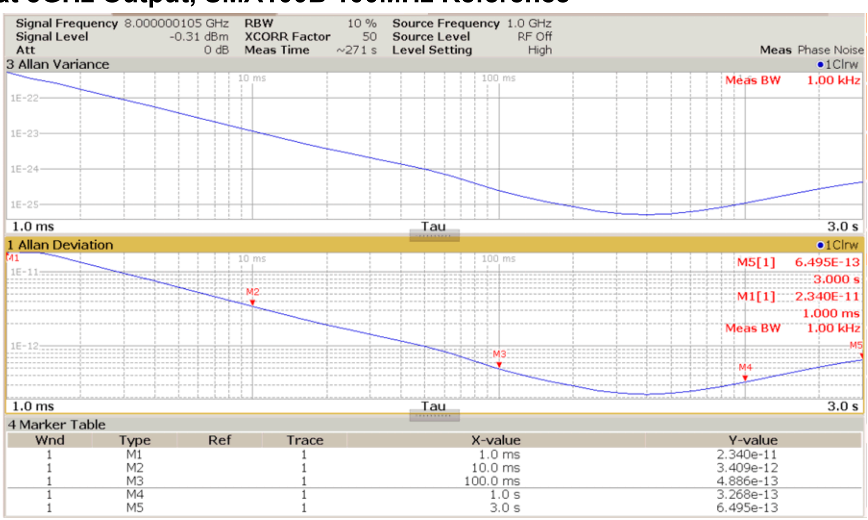

Figure 3. LMX2624 at 8GHz Output, SMA100B 100MHz Reference

Case 4: LMX2624 at 8GHz Output, Wenzel 100MHz Reference

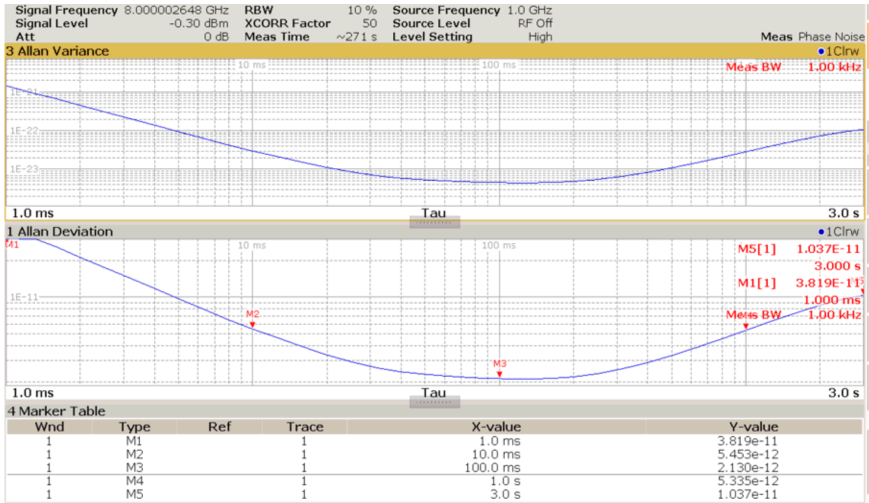

Figure 4. LMX2624 at 8GHz Output, Wenzel 100MHz Reference

Summary of the Allan Deviation Data

As the Tau increases (shown in Table 3), both LMX2615 and LMX2624 gives similar results because the limitation comes from the input reference source. This is valid for both Wenzel and SMA100B reference.

Table 3. Summary of the Allan Deviation Data at 8GHz Output

Tau(at 8GHz)	SMA-LMX2615	SMA-LMX2624	Wenzel-LMX2615	Wenzel-LMX2624
10msec	3.19e-12	3.4e-12	2.75e-12	5.45e-12
100msec	4.6e-13	4.88e-12	1.54e-12	2.13e-12
1sec	3.23e-13	3.26e-13	5.076e-12	5.33e-12
3sec	6.62e-13	6.49e-13	8.46e-12	10.37e-12

Analysis of Reference Sources

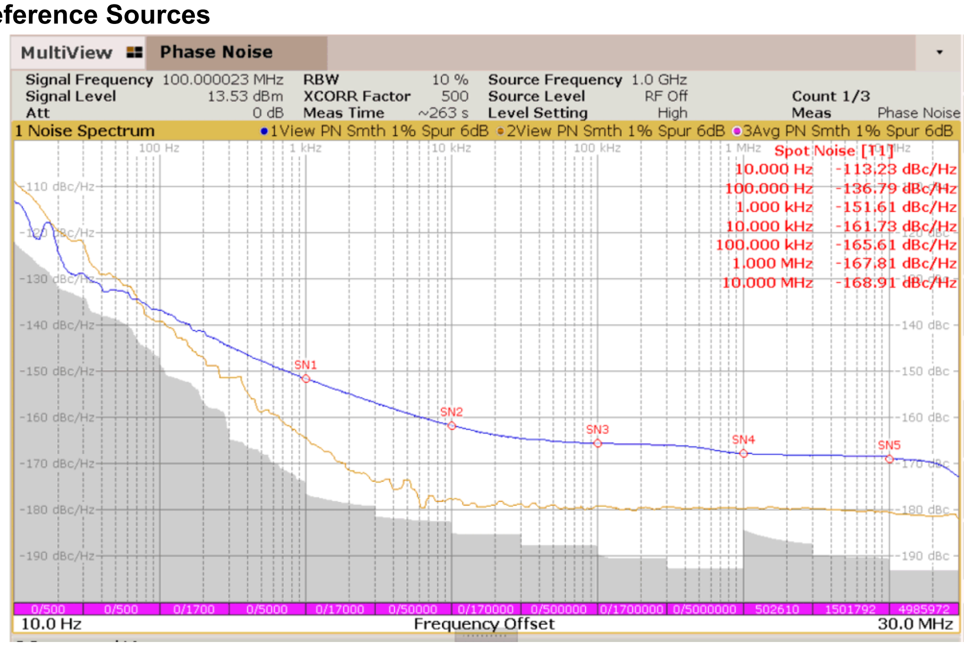

Figure 5. SMA100B vs Wenzel 100MHz Phase Noise Comparison

Table 4. Reference Allan Deviation Comparison

Sigma at Tau(Allan deviation)	SMA100B(100MHz)	Wenzel(100MHz)
1msec	4.9e-12	2.1e-12
10msec	1.19e-12	1.5e-12
100msec	2.56e-13	1.44e-12
1sec	3.38e-13	7.36e-12
3sec	6.98e-13	13.6e-12

Observations

All the above cases discussed are with 100MHz and close to 10dBm power for the reference input. But for some cases, reference frequency is lower such as 5 or 10MHz due to the low cost implementations. These cases have low slew rate and PLL noise increase. Figure 6 is a case where reference is 5MHz in LMX2615.

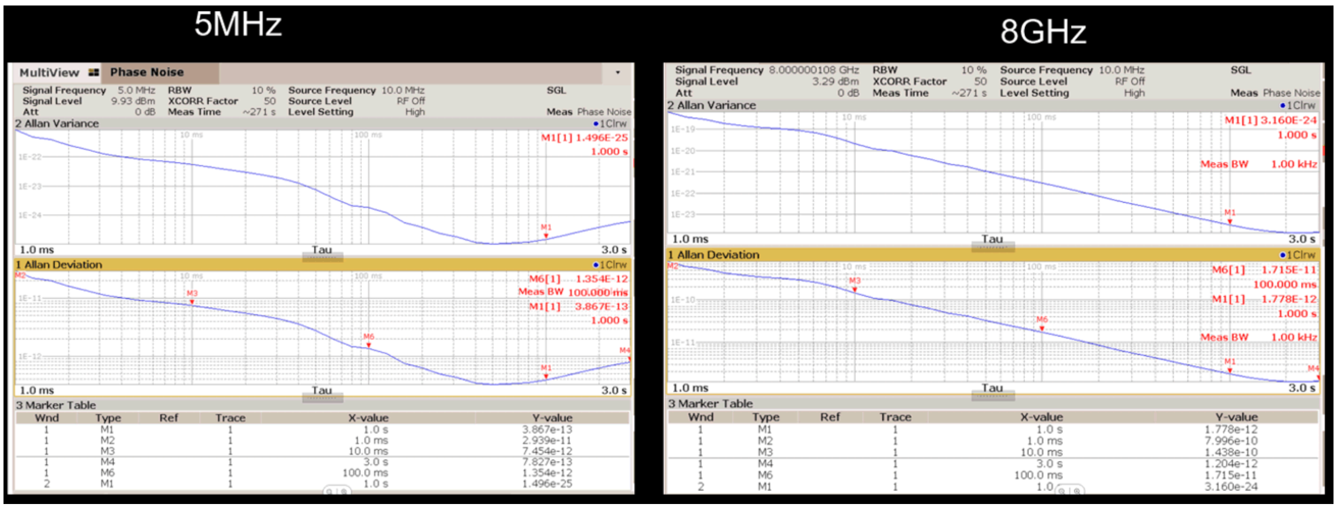

Figure 6. LMX2615 at 8GHz Output, SMA100B 5MHz Reference

References

1. IEEE, *A Historical Perspective on the Development of the Allan Variances and Their Strengths and Weaknesses*
2. Rohde & Schwarz, *Time Domain Oscillator Stability Measurement Allan variance*, application note.
3. IEEE, *Oscillator Phase Noise: A 50-Year Review*
4. Rohde & Schwarz, *R&S FSWP PHASE NOISE ANALYZER Specifications.*, specifications.

Trademarks

All trademarks are the property of their respective owners.

IMPORTANT NOTICE AND DISCLAIMER