Fast, Easy, and Accurate Microwave Phase Noise Measurements using the Agilent E5052B SSA with the E5053A

Application Note

Agilent Technologies

Today's evolution in high-speed semiconductor technologies such as RF-CMOS, GaN, and SiGe are continuing to push the application frequency limit up higher and higher in microwave and millimeter-wave ranges. As the requirements of new commercial market applications such as automotive radars, UWB communication links and wireless LAN/PAN, as well as traditional aerospace and defense applications become more rigid, characterizing phase noise of a signal source is getting more important than ever. In addition, a simple and cost-effective method to evaluate phase noise when testing as many parameters as possible in microwave signal sources, is expected.

The Agilent E5052B Signal Source Analyzer (SSA), along with the E5053A Microwave Downconverter, has an extended frequency range up to 26.5 GHz. Shown in Figure 1, all six fundamental functions available in the E5052B (10 MHz to 7 GHz) are now usable up to 26.5 GHz with the E5053A. The phase noise measurement capability can be extended to 110 GHz with external harmonic mixers supplied by Agilent or third parties.

Figure 1. Six fundamental functions of the E5052B

The E5052B SSA offers excellent phase noise sensitivity at microwave carrier frequencies. The maximum offset frequency range for phase noise analysis is from 1 Hz to 100 MHz in Normal capture mode or 40 MHz in Wide capture mode. The Wide capture mode is useful when measuring relatively drifty oscillators.

In Figure 2 the measured result shown is 21.55 GHz. You can see the E5052B and the E5053A captured sub-picoseconds jitter (phase noise) at 21.55 GHz or at 43.10 GHz clock-rate equivalently. Typical phase noise floors at microwave frequencies are shown in Figure 3.

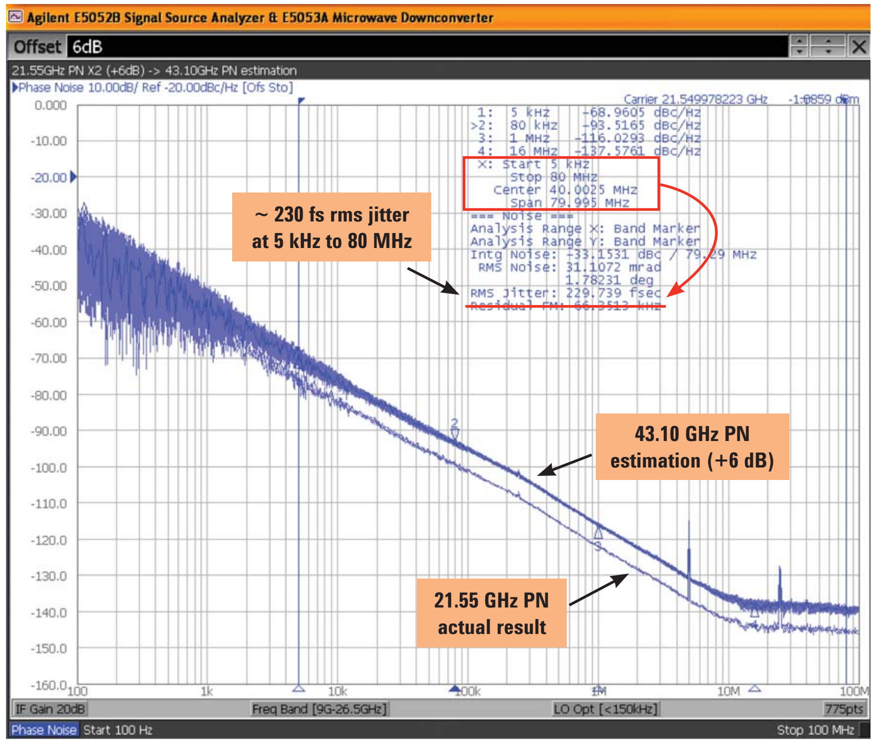

Figure 2. 21.55 GHz jitter measurement by the E5053A

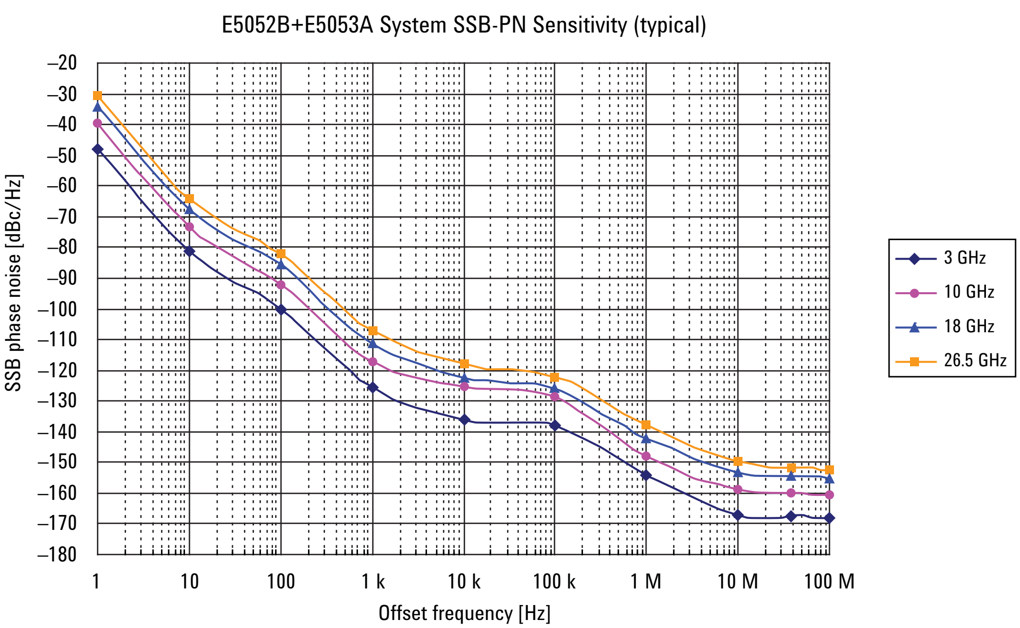

Figure 3. E5053A system phase noise floor

The E5052B's measurement speed in phase noise is very fast compared to a conventional direct spectrum analyzer method or a traditional PLL method. For example, the measurement throughput is only less than a half second at 1 kHz to 100 MHz offset frequencies, and about 13 seconds at 1 Hz to 100 MHz offset frequencies. This level of phase noise measurement throughput is more than ten times faster compared with conventional methods thanks to a 100 MHz real-time baseband analyzer with 250 MSps.

The E5052B's two channel cross-correlation technique (random noise cancellation technique) in low phase noise measurement can reduce the noise floor by 20 dB maximum (depending on the number of correlation). Although increasing the number of correlation causes longer measurement time, the total measurement time will still remain within a reasonable range shown in Figure 4. Noise reduction effectiveness (ratio) by using the cross-correlation technique is shown in Figure 5.

For quiet (very low phase noise) signal sources in microwave the E5052B and the E5053A can provide excellent sensitivity in Normal capture mode (a PLL method) and ultra-low noise floor by adopting the cross-correlation technique previously mentioned.

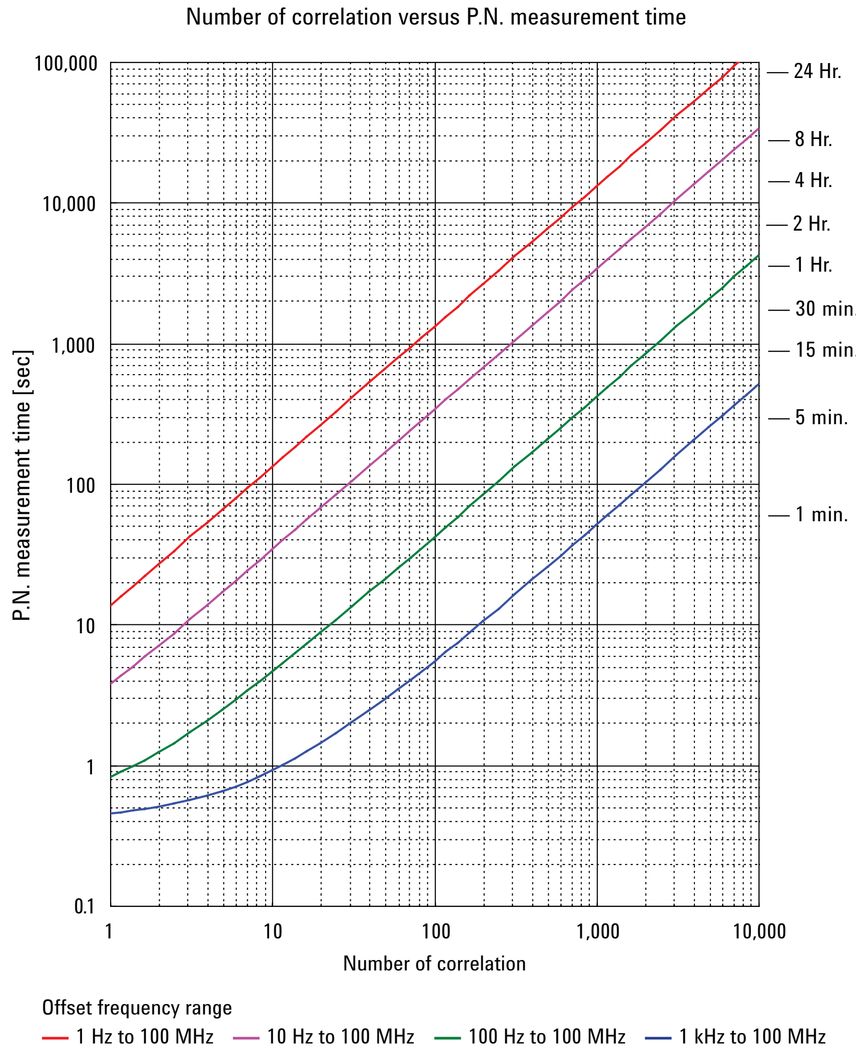

Figure 4. Number of correlation versus PN measurement time

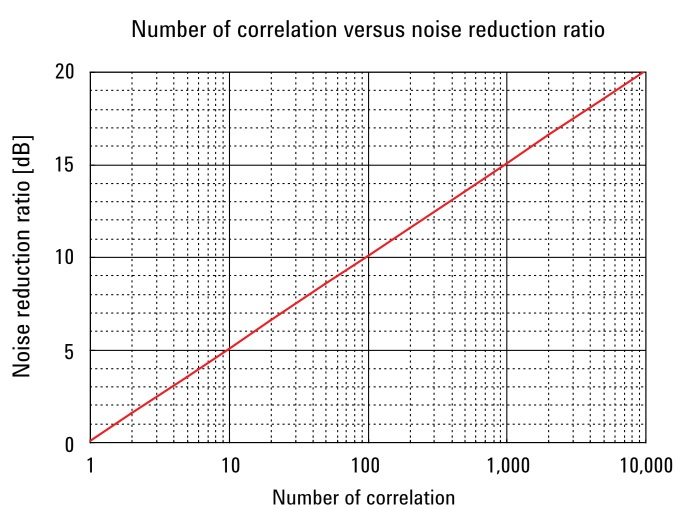

Figure 5. Number of correlation versus noise reduction ratio

However, we sometimes have to characterize somewhat noisy oscillators that are often accompanied with drift or wander in microwave or millimeter-wave. For signal sources above 400 MHz the E5052B can offer an alternative phase noise measurement method in Wide capture mode, called a heterodyne digital discriminator method, because the PLL method fails to capture a noisy signal due to its limitation of system response bandwidth and operation of phase detectors.

Details of both the PLL method and the heterodyne digital discriminator method are described in E5052B's Application Note *Advanced Phase Noise and Transient Measurement Technique* (publication number 5989-7273EN). Although in the Wide capture mode the maximum offset frequency range is limited to 40 MHz (instead of 100 MHz of the Normal capture mode) about 10 dB to 30 dB extensions in higher phase noise measurement range can be achieved. This feature shows a clear advantage when characterizing a free-running voltage controlled oscillator. The measurement example shown in Figure 6 displays "System PLL unlocked" warning in the Normal mode, which indicates a correct result for a noisy 24 GHz signal source in Wide capture mode.

The E5052B and the E5053A also provide accurate power and frequency measurements along with amplitude modulation (AM) noise measurement without any re-connection at an RF input port. Figure 7 shows another example of measurement results at 24 GHz.

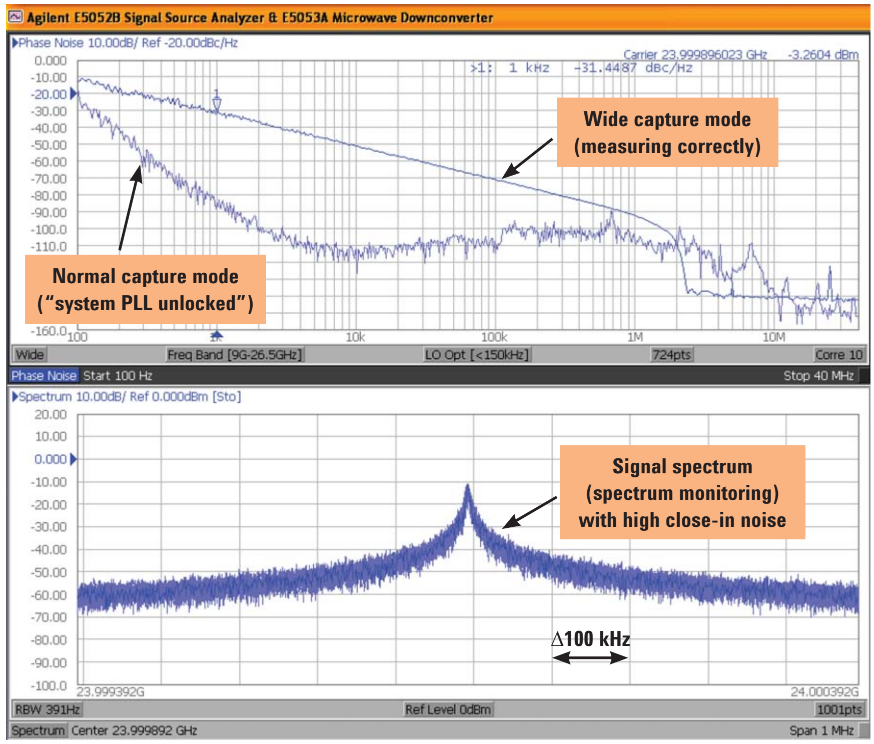

Figure 6. 24 GHz noisy signal source measurements

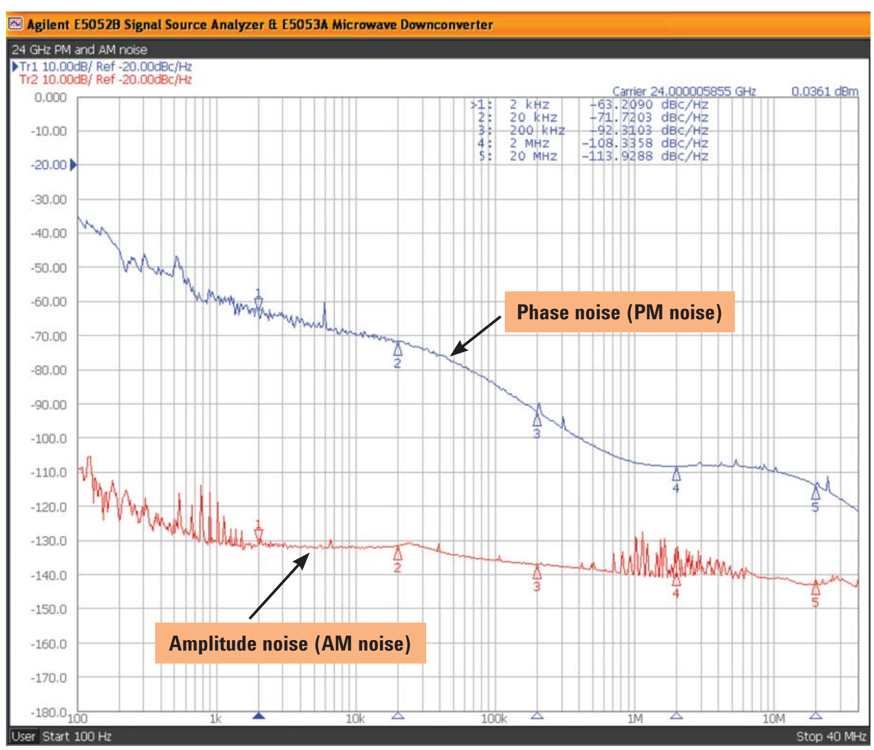

Figure 7. 24 GHz PM and AM noise

Figure 8 shows a simplified block-diagram of the E5053A/E5052B and it's relationship among several reference signals by measurement mode. Note that "Reference Signal 2" acts as a key role in PN and frequency measurement accuracy. The appropriate "Reference Signal" connection is very important to keep measurement repeatability and stability.

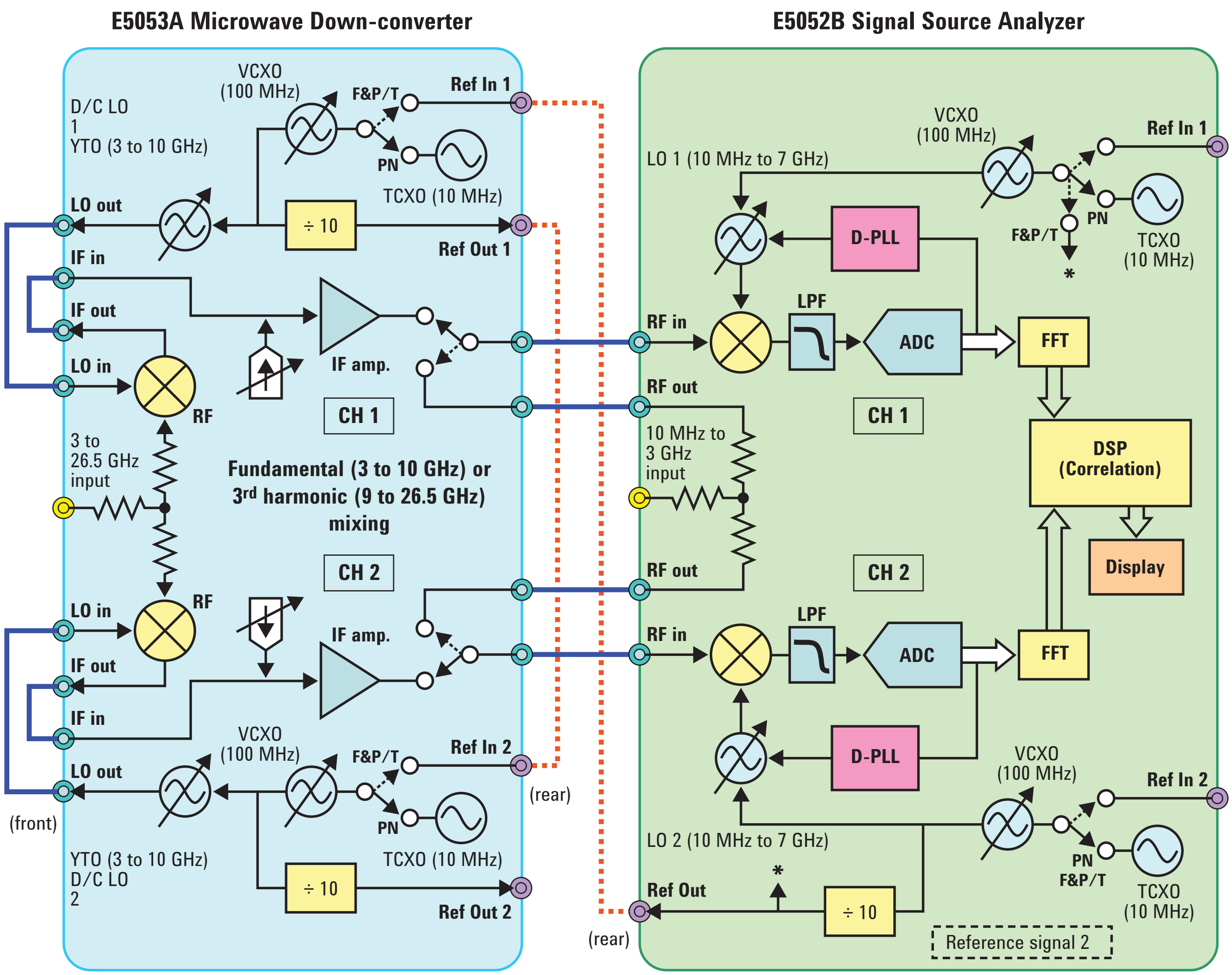

Figure 8. Internal reference signal connection diagram for E5053A + E5052B

Extending phase noise measurements into millimeter-wave above 26.5 GHz is easy because the E5052B and the E5053A are designed to use two independent paths (signal channels) for down-conversion from RF to IF. A power splitter (power-divider) and a pair of external harmonic mixers can be added to the E5053A as shown in Figure 9, in order to utilize the cross-correlation method up to 110 GHz. The “mmW Application” software equipped in the E5052B assists in setting the local oscillators frequencies.

For more information on mmW application refer to *Fast and Simple Phase Noise Measurements in mmW* (publication number 5989-8372EN) and E5052B user’s guide (help file, chapter 10 “Measurement Using E5053A and External Mixer”)

Agilent E5052B Signal Source Analyzer is designed to test phase noise at microwave and millimeter-wave frequencies accurately. The exceptional low phase noise sensitivity and wide dynamic range with simplified operation is achieved by utilizing a cross-correlation (random noise cancelling) technique, a heterodyne digital discriminator method, and a low noise 100 MHz real-time baseband analyzer with 250 MHz sampling rate.

The E5052B’s performance for phase noise measurements, signal source characterization of free-running VCO parameters, and transient response parameters provides the most accurate and reliable measurement results in microwave component evaluation.

Web resources

Visit our Signal Source Analyzer Web site for additional product information and literature:
www.agilent.com/find/ssa

Phase noise measurements:
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Figure 9. mmW application with harmonic mixers

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