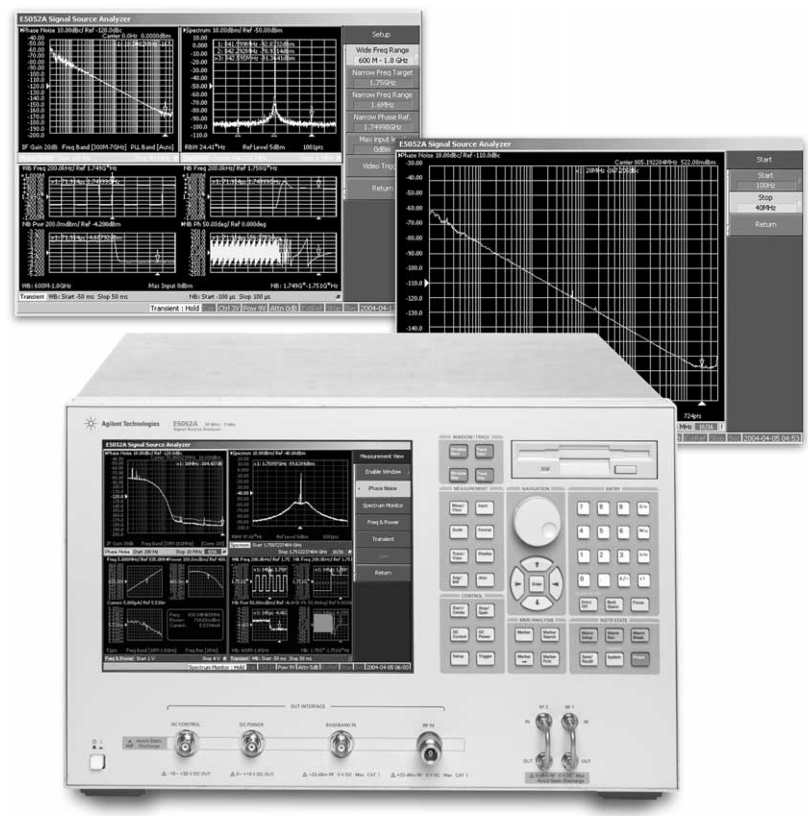
Agilent
E5052A Signal Source Analyzer

Advanced Phase Noise and Transient Measurement Techniques

Application Note



Introduction

The Agilent E5052A signal source analyzer is designed to help R&D and manufacturing engineers across a wide range of electronic industries perform signal source tests more accurately, at lower cost, with unprecedented simplicity. SSA provides a complete set of measurement functions for full characterization of signal sources. Each of the SSA's measurement functions delivers performance that is comparable to or exceeds that of conventional dedicated test instruments and systems. This document describes conventional signal source measurement techniques and the advanced measurement techniques of Agilent's SSA:

- Phase noise measurement
- Transient measurement

1. Phase Noise Measurement

1-1. Problems with conventional test solutions

Traditionally, dedicated phase noise test systems have been used to accurately evaluate the phase noise of signal sources. The most commonly used measurement method of those test systems is the **reference source/PLL technique**. However, the reference source/PLL technique has several drawbacks.

- The measurement process is complicated. To configure the test system, an external reference source must be prepared according to measurement needs. A signal generator is typically used as a reference source for many types of DUTs. However, if you want to measure close-in phase noise of crystal oscillators, you must prepare your own special reference source such as a ultra-low noise VCXO; which has better phase noise performance than the DUTs. After the system is configured, a complicated setup and calibration must be performed.

- Measurement sensitivity is limited by the noise floor of the reference source. Consequently, it is difficult to satisfy today's measurement needs which demand extremely rigorous test specifications, such as the test requirements for GSM (< –165 dBc/Hz at 20 MHz offset).

- When measuring oscillator phase noise using a high peak-tune-range, phase locking can be troublesome with a test system. Often, phase locking problems will occur and can result in lots time spent calibrating the system.

Another common measurement method of conventional phase noise test systems is the **delay-line technique**. This method provides very high sensitivity at far-from-carrier offset ranges. Furthermore, it satisfies the test requirement for GSM. However, again, the delay-line technique has several drawbacks:

- The measurement process is complicated. It is necessary to use several different delay lines according to the test frequency ranges. In addition, a complicated calibration must be performed for each delay line.

- It is not possible to measure phase noise at close-to-carrier offset ranges because it requires a delay line that is too long to be practically feasible.

- It is difficult to measure DUTs that have low RF output power, as the phase detector may not be driven correctly due to the power loss in the delay line.

1-2. SSA's innovative phase noise measurement techniques

Agilent's SSA solves all the previously mentioned issues. The SSA's phase noise measurement function provides high sensitivity that surpasses the conventional dedicated phase noise test systems with much faster speed and greater ease in operation. The following content will provide more detail regarding SSA's innovative phase noise measurement techniques.

1-3. Exceptional phase noise measurement sensitivity

Figure 1 shows the phase noise measurement sensitivity of the Agilent E5052A signal source analyzer. SSA has an extremely low noise floor across the entire offset frequency range. Figure 2 and 3 show measurement examples of a crystal oscillator and a VCO for GSM. As shown in these examples, the analyzer can accurately measure low phase noise at both the close-in-carrier and far-out-carrier by just connecting the DUTs and pushing a few buttons, whereas the conventional test solutions require two complicated procedures involving a reference source and a delay line.

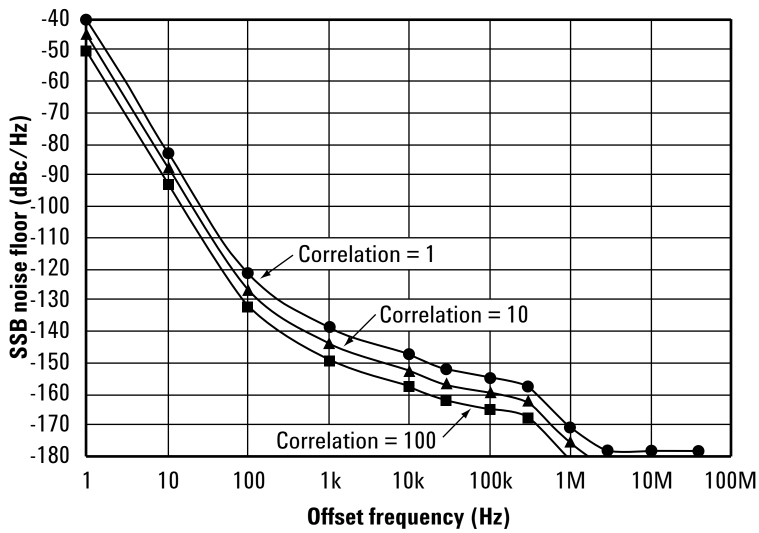


Figure 1. E5052A's Internal SSB phase noise (carrier= 1 GHz, correlation= 1, 10, 100)

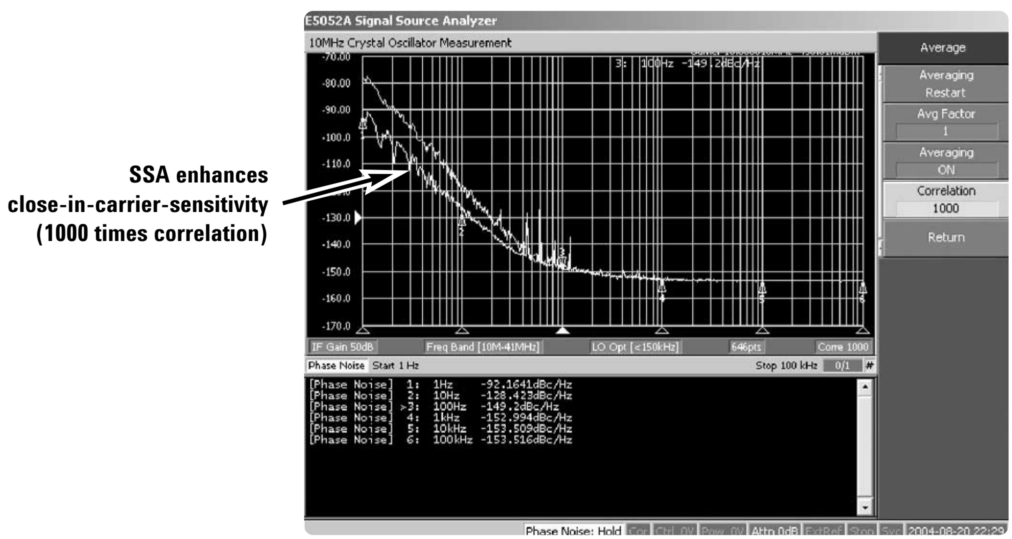


Figure2. Low phase noise crystal oscillator measurement using the cross-correlation technique

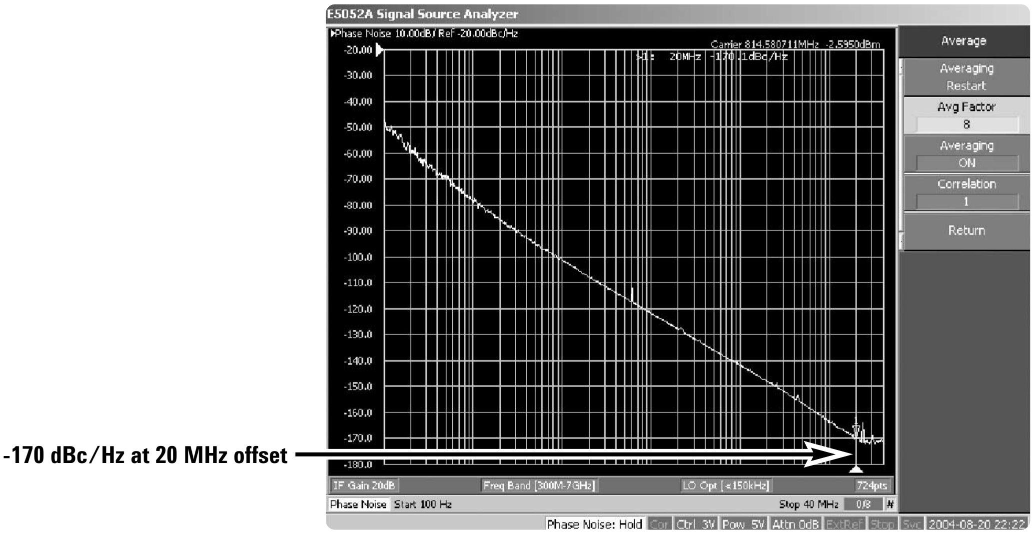


Figure 3. Free-running VCO measurement with high sensitivity of far-out offset frequencies

There are two major contributors to SSA's breakthrough performance. One is the newly designed, built-in, low-noise reference source. The other is the cross-correlation technique that further reduces the test system noise. The cross-correlation technique essentially cancels noise by taking the vector sum of the measurement results of two independent measurement channels. As shown in Figure 4, the signal source analyzer includes two independent PLL paths with two built-in reference sources that are uncorrelated with each other. If two signals are uncorrelated, their vector sum (meaning the total noise power from the reference sources can be degraded by taking vector averaging) lowers the system noise floor by canceling the noise from its internal reference sources and other related circuits, while the noise signal from the DUT is emphasized.

The degree of noise cancellation depends on the number of correlations; as shown in the equation in Figure 5. For example, 100 times correlation produces a 10 dB noise floor improvement.

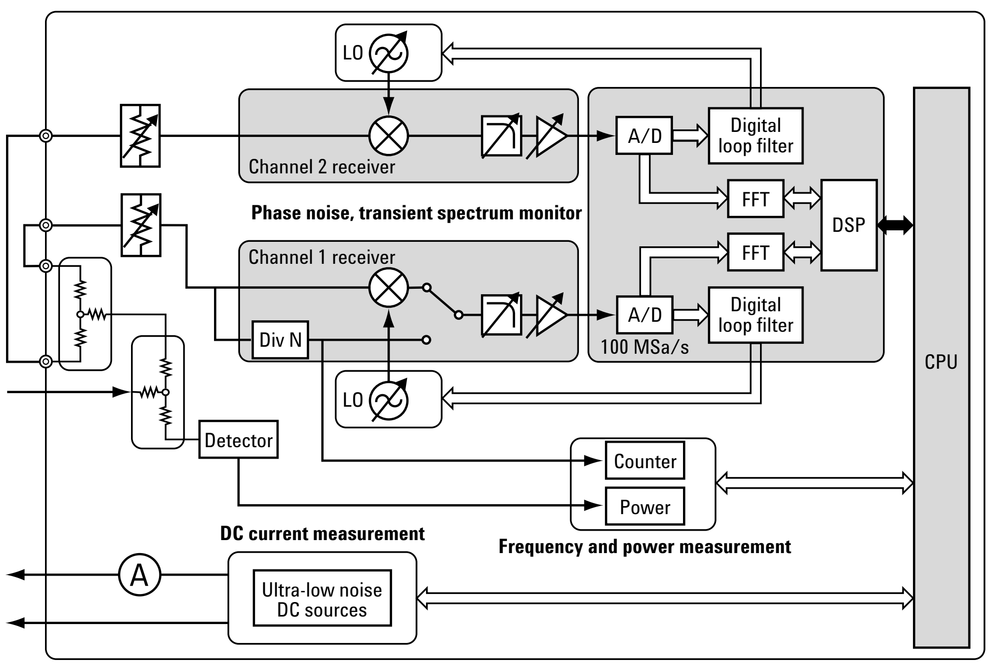
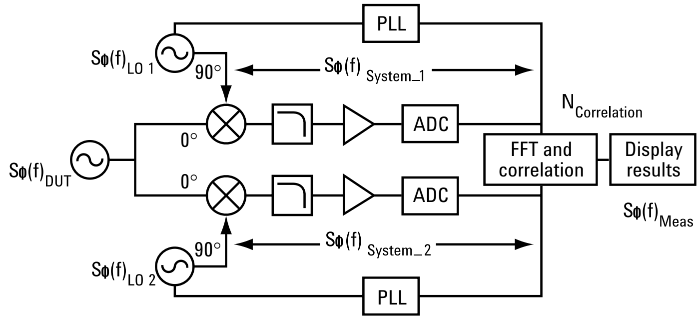


Figure 4. Agilent E5052A signal source analyzer block diagram



$$S\phi(f)_{Meas} = S\phi(f)_{DUT} + \frac{S\phi(f)_{LO\,1} + S\phi(f)_{LO\,2} + S\phi(f)_{System\_1} + S\phi(f)_{System\_2}}{\sqrt{N_{Correlation}}}$$

Figure 5. Cross-correlation implementation on the E5052A signal source analyzer

1-4. Easy, one-step phase noise measurements

The signal source analyzer provides a true one-step phase noise measurement by eliminating time-consuming procedures. With the SSA, it is no longer necessary to perform time consuming and complicated calibrations. SSA provides all phase noise measurement circuits and other measurement capabilities in one instrument, enabling users to automatically perform self-calibration. For example, the analyzer's built-in frequency counter and power meter functions are internally used to calibrate the PLL circuits. Compared to conventional phase noise test solutions, which require lots of time to manually set up and calibrate, SSA's self-calibration is completed before making a phase noise measurement in a negligible amount of time. Moreover, the analyzer provides better PLL tracking of the DUT's drift than conventional phase noise test solutions; and the integrated reference sources are automatically controlled to maintain the phase locking.

1-5. Comparison of phase noise measurement techniques

Table 1 shows a comparison with conventional phase noise measurement methods. The E5052A's innovative phase noise measurement technique provides the best combination of performance and ease-of-use. Not only does the SSA dramatically improve phase noise measurement quality and efficiency but also eases frustration for people who may typically avoid phase noise measurements due to their complexity.

Table 1. Comparison of phase noise measurement techniques

Phase noise measurement method	Advantages	Disadvantages
Direct spectrum analysis	• Easy operation • Enables quick check of locked signals	• Cannot measure close-in-carrier phase noise such as crystal oscillators • Cannot measure drifting signals such as free-running VCOs • Cannot separate AM noise from the reference source used
Reference/PLL method	• Applicable to broad offset range • Measures very low phase noise at close-in-carrier using internal low noise reference sources (such as crystal oscillators)	• Phase noise sensitivity is limited by noise • Requires complicated setup and calibration
Delay line method	• Measures very low noise at far-out-carrier offset • Suitable for measuring high drifting oscillators such as YIG oscillators	• Not applicable for close-in-carrier phase noise measurement • Requires complicated setup and calibration
Signal source analyzer (Dual reference source/PLL with cross-correlation)	• Easy operation eliminates complicated setup and calibration • Measures very low noise at broad offset ranges • Cross-correlation enhances phase noise sensitivity of the system	• Longer measurement time for extremely low phase noise floor with close-in-carrier measurements

2. Transient Measurements

The SSA's transient measurement capability satisfies the requirements and advanced functionality of current and future high speed synthesizer evaluation.

2-1. Dual channel measurements

SSA offers a major breakthrough in transient measurements for synthesizers. The analyzer performs wideband (maximum 4.8 GHz span) and narrowband (25.6 MHz or 1.6 MHz span) transient measurements in parallel by using dual measurement paths as shown in Figure 6. To improve the efficiency of synthesizer evaluations, the SSA enables observation of both the entire picture of frequency jumps and as well as detailed frequency/phase/power transient over time, simultaneously.

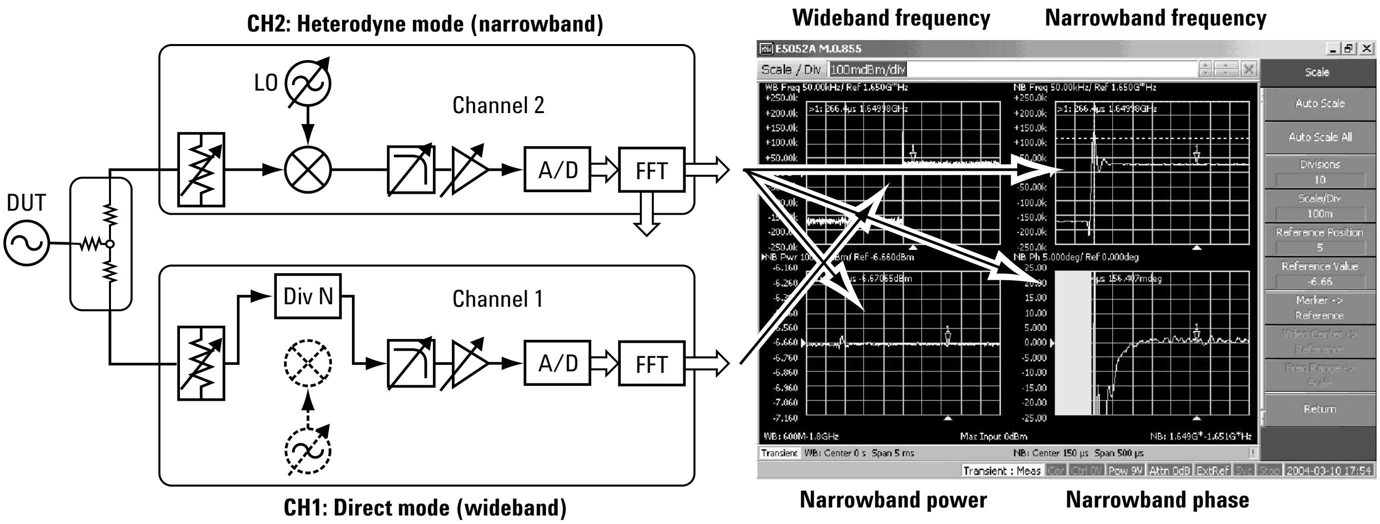


Figure 6. Block diagram of signal source analyzer's dual channel measurement

2-2. Fast sampling, high frequency resolution

The SSA's fast sampling capability with a 100 MHz A/D converter enables 10 nsec time resolution in the narrowband mode, while maintaining high frequency resolution. Figure 6 compares the signal source analyzer's time and frequency resolution with a modulation domain analyzer (MDA) that has been commonly used for synthesizer transient measurements. As this comparison reveals, the signal source analyzer provides time and frequency resolution more than ten times better than an MDA.

Figure 7 shows an actual transient measurement comparison between the SSA and MDA in the same time span. This example illustrates the signal analyzer's superior frequency resolution.

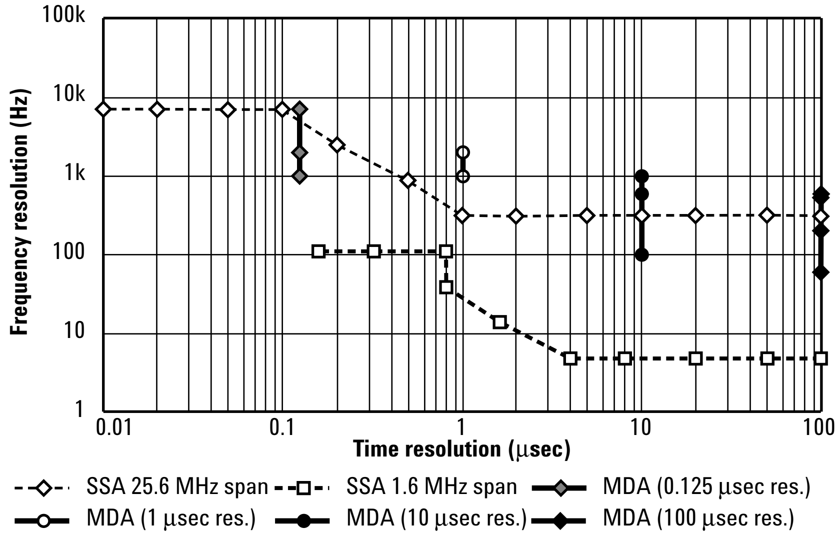


Figure 7. Time and frequency resolution comparison of the signal source analyzer verses a modulation domain analyzer

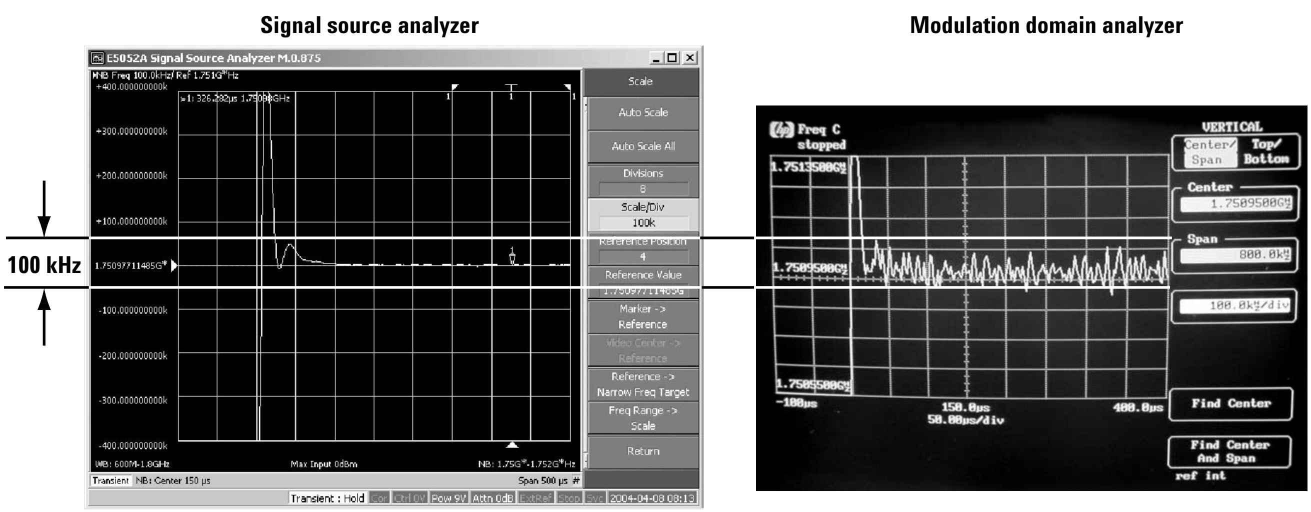


Figure 8. Comparison of SSA and MDA transient measurements

Conclusion

The Agilent E5052A signal source analyzer is designed to perform tests more accurately, at lower cost, with unprecedented simplicity. It provides all of the critical performance characteristics of nearly every type of signal source and can speed signal source measurements by a factor of 10. The SSA is a single instrument solution that replaces the need for large, complex racks of test equipment.

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