Measuring Oscillator Sensitivity with an RSA

The present demand for high performance, high speed A/D converters, has focused the engineering community on the jitter performance of high speed oscillators and clocks. Clock jitter drives many performance characteristics such as SINAD, SNR, BER and ENOB, just to name a few.

While the manufacturers of these clocks provide jitter data, this data is generally extracted in a very controlled, and very particular, environment. The clock performance is impacted by many performance characteristics of the voltage regulator that powers the clock, as well as, the performance characteristics of the clock itself, including frequency sensitivity to the supply voltage (generally referred to as clock PSRR).

Clock jitter is very sensitive to power supply variations and, therefore, measuring this jitter is an excellent method of measuring power supply noise, albeit indirectly.

This application note demonstrates the use of the Tektronix RSA5106A real time spectrum analyzer, in conjunction with the Picotest Signal Injectors, to assess oscillator performance. The RSA5106A has many features that make this an ideal instrument for making clock measurements. In this application note we will show the measurement of AM and FM modulation, as well as phase noise and total jitter resulting from the clock's power supply. A picture of the test setup is shown in Figure 1. A Tektronix DPO5104 oscilloscope is used to monitor the input injection signals while the RSA5106A is used to monitor the clock output.

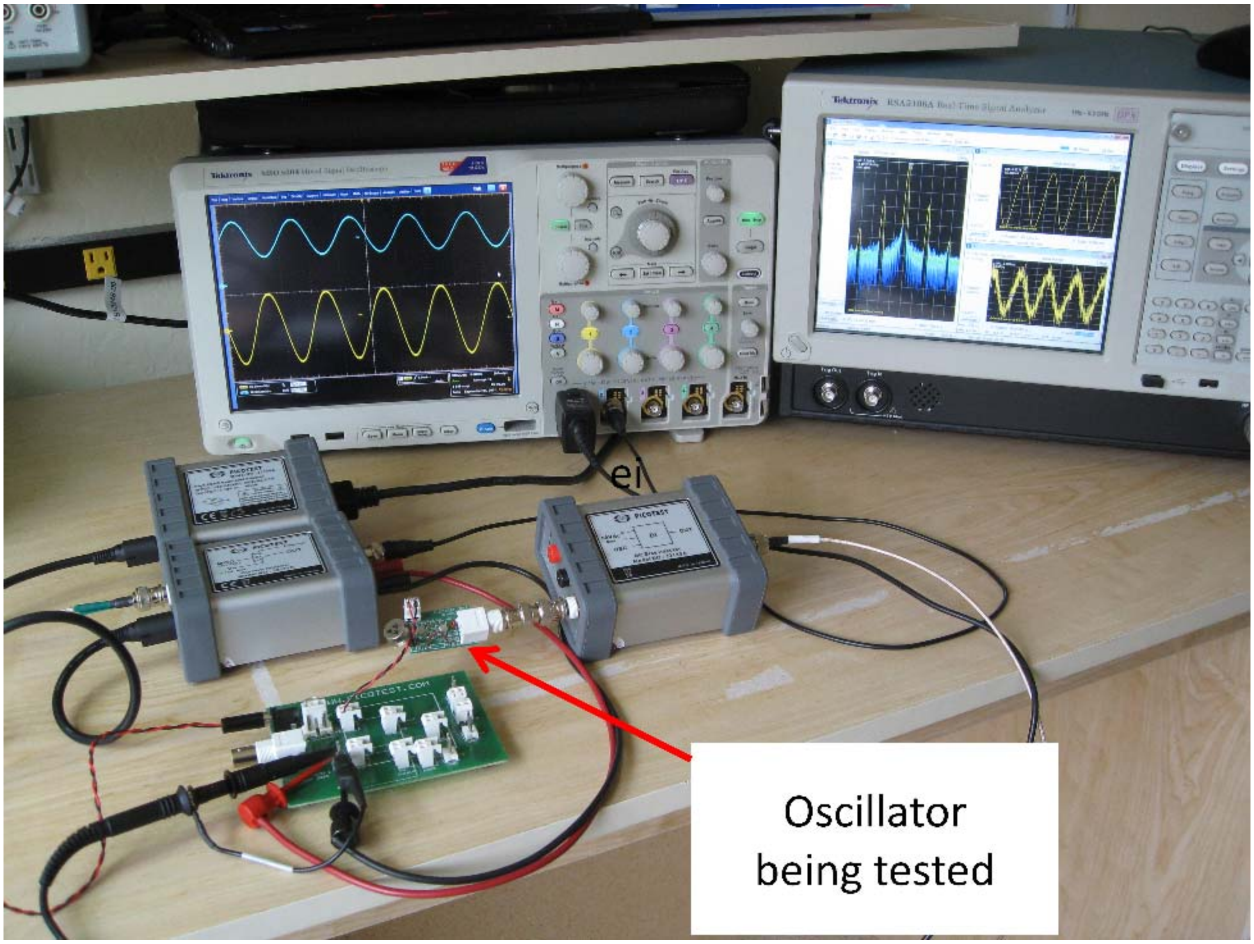

Figure 1 – The test setup for measuring clock and oscillator performance.

The oscilloscope in Figure 1 is displaying the injected signal current (upper, blue trace) and the resulting power supply ripple voltage (lower yellow trace). The Picotest Signal Injectors on the left are the J2111A Current Injector and the J2170A high PSRR power supply, especially designed to keep noise out of the injected signal. These two are used to generate a perturbing load step current signal on the output of the regulator under test emulating in-system transient conditions. The Injector on the right is a DC Bias injector, which contains a bank of high performance capacitors supporting a bandwidth as low as 100Hz. The DC Bias injector is used as a high performance, low frequency DC blocker. The Picotest VRTS board is used as a test bed mainly due to its input isolation resistor and also the ability to facilitate the testing of different voltage regulators. The RSA is used to measure the phase noise and the clock jitter resulting from the regulator output noise.

The particular oscillator being evaluated in this application note is a grounded base oscillator, using a high Q, AT-cut fundamental crystal. The phase noise measurement is a difficult measurement due to the crystal's very high Q, which results in very low sensitivity. Nonetheless, the measurement is made easily and accurately using the RSA5106A. The injected current from the J2111A develops a voltage across the 2 Ohm VRTS isolation resistor. The injected current and the resulting voltage at the oscillator input power supply are shown in Figure 2. The use of the J2111A to inject a current signal allows this measurement to be made without breaking or disconnecting any wires. This measurement can also generally be made "in-circuit", using the source impedance of the oscillator power source rather than an isolation resistor.

The oscillator measurements are shown in Figure 3. The upper trace shows the center frequency along with the sidebands at +/- 1kHz, (the injection frequency). The RSA5106A also displays the AM and FM results, both of which contribute to phase noise.

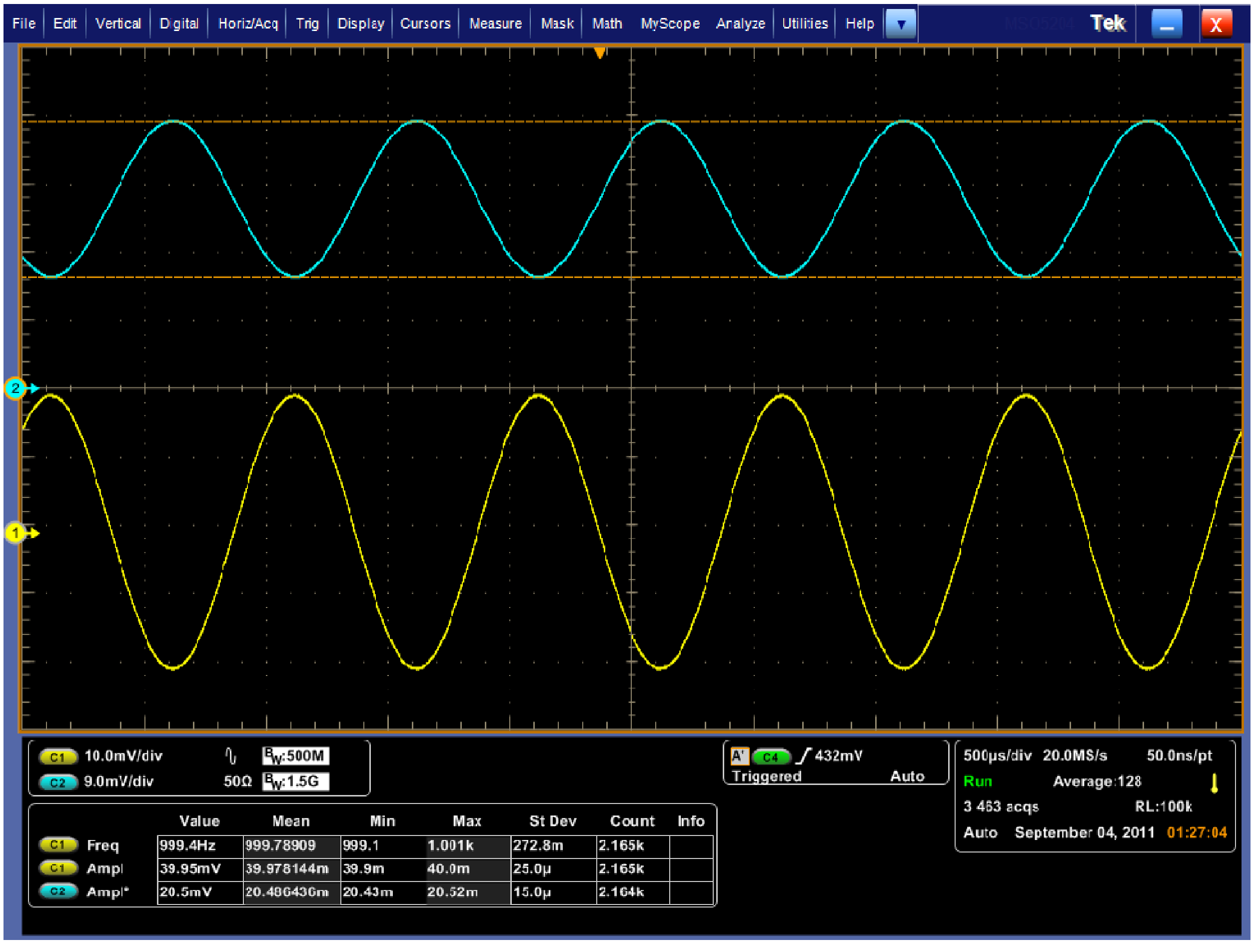

Figure 2 – The J2111A injects a 20mApp current at 1kHz. The signal is set using an AWG or function generator and can be any signal function. A sine wave is used to show a clean, single frequency result in this measurement.

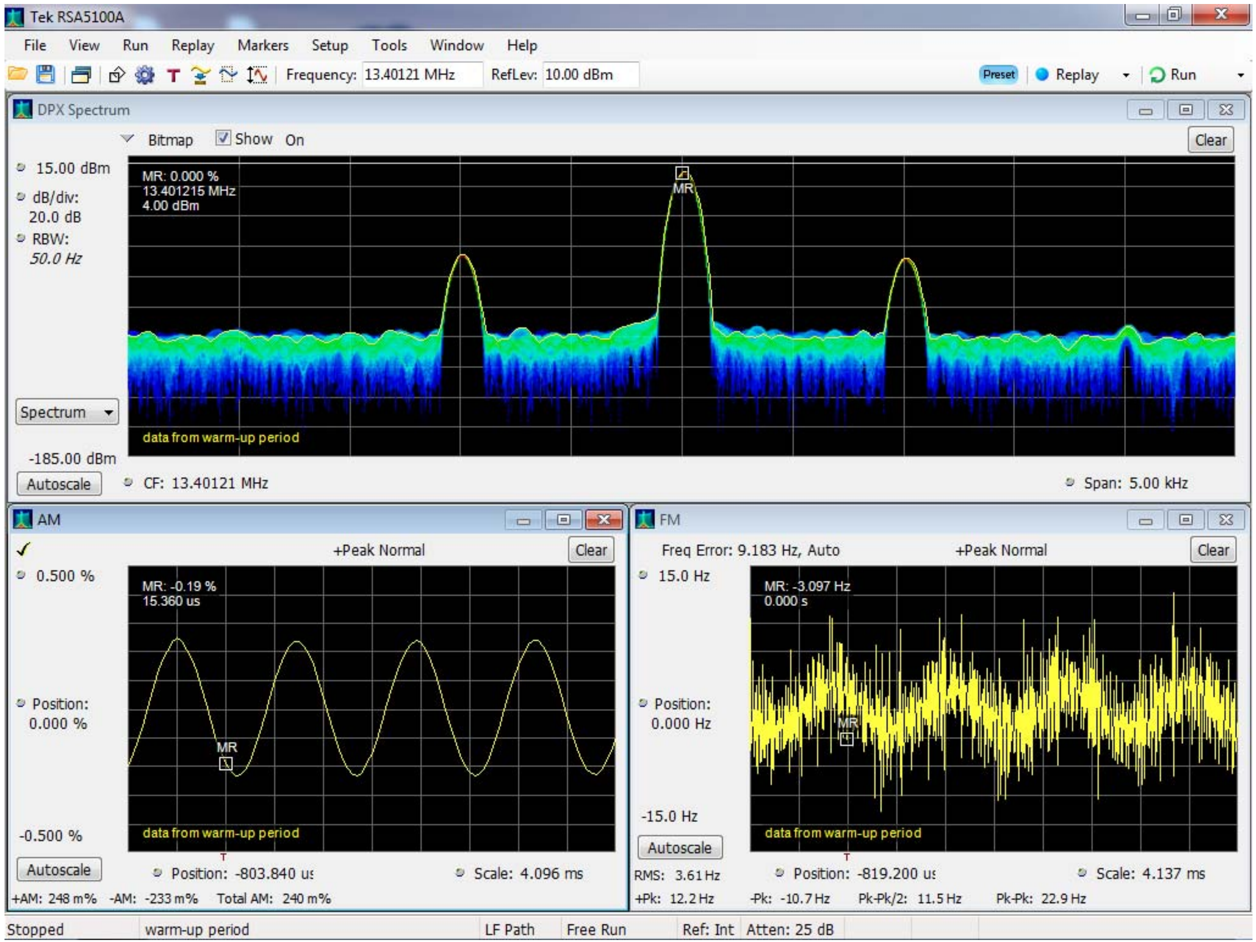

Figure 3 - Results of the oscillator measurement with a 40mVpp 1kHz ripple voltage imposed on the power supply feeding the oscillator. The RSA5106A can display the AM and FM results separately. The FM plot displays 3.66Hz RMS variance while the AM plot indicates approximately 0.22% pk modulation.

The RSA5106A directly provides the frequency sensitivity (approximately 6Hzpp/0.04) or 150Hz/V corresponding to 11.2ppm/V based on the 13.401Mz carrier frequency.

Since Figure 3 shows that the majority of the modulation, in this case AM (0.44% AM compared with 6Hz FM), we can calculate the modulation using the amplitude of the sidebands relative to the carrier. In this case, the sidebands are -55dBc.

Calculating the AM %

$$dBc := -55 \qquad AM := \sqrt{2}\cdot 10^{\frac{dBc}{20}} \qquad AM = 0.251\%$$

The calculated modulation is very close to the measurement.

The RSA5106A can also display phase noise as shown in Figure 4, which shows the 1kHz spur resulting from the 1kHz injected load step signal. The RSA5106A can easily provide the total jitter, however, a phase noise measurement alone cannot discern between FM and AM modulation of the oscillator .

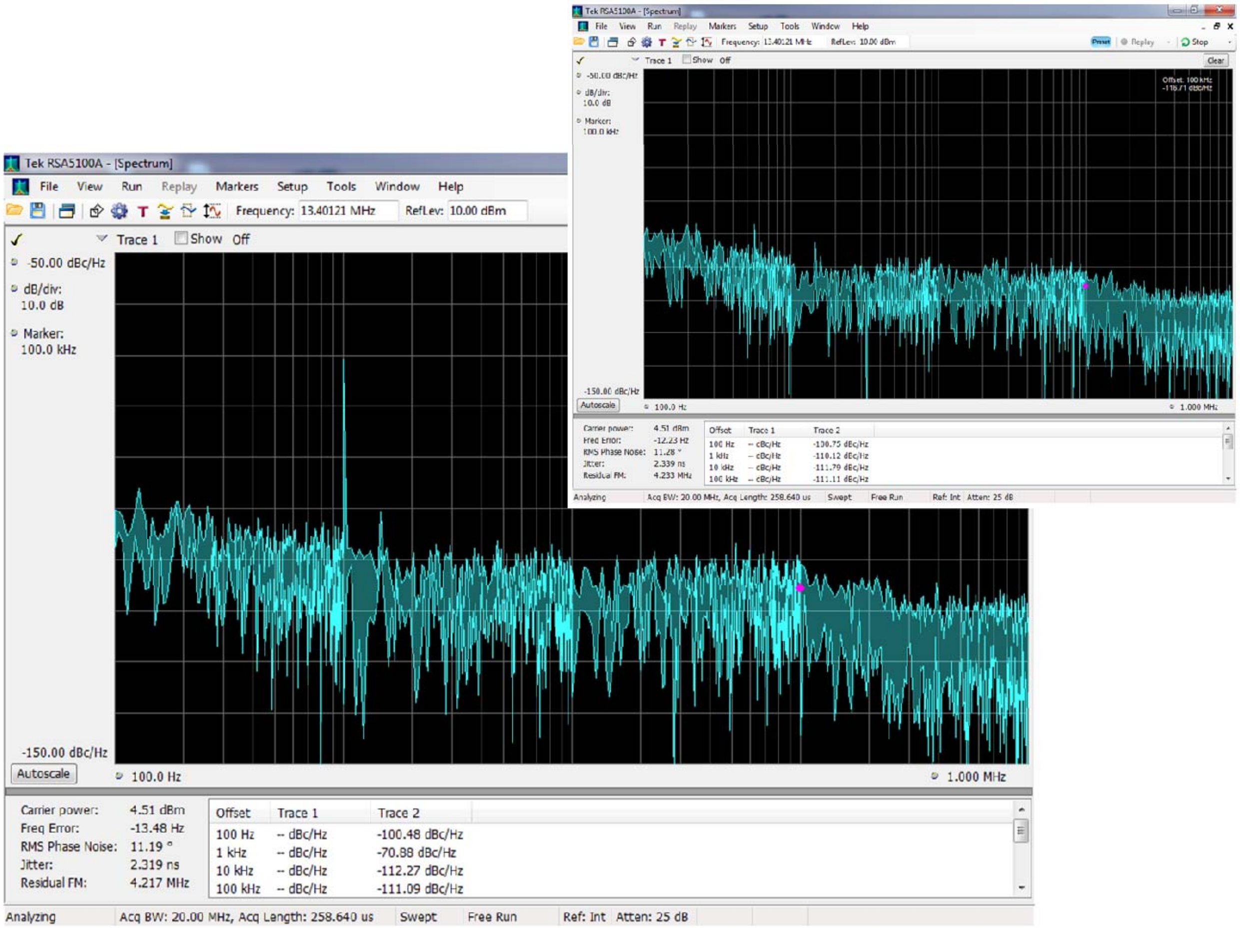

Figure 4 The phase noise of the oscillator with (left) and without the injected regulator load step signal. This result shows how easy it is for your power system to corrupt the phase noise of the clock.

The measurement setup discussed above can be modulated by waveforms other than pure sine waves. The following results show the performance of a 13.4MHz Arbitrary Waveform Generator (AWG) using AM modulation and FM modulation, independently. In both cases the modulation is a 1kHz square wave signal. Figure 5 shows the results of 0.2% AM and no FM while Figure 6 shows the results of 1kHz FM and no AM.

Some Insight into the measurements

Using an AWG, we can show that both AM and FM are represented similarly in the phase noise measurement. Figure 5 shows the AM and FM signal measurements on the RSA5106A. The center frequency is set to 13.4MHz and the AM is set to 0.2%. Note that the FM only shows the oscillator noise, as there is no evidence of the 1kHz square wave signal in the FM window.

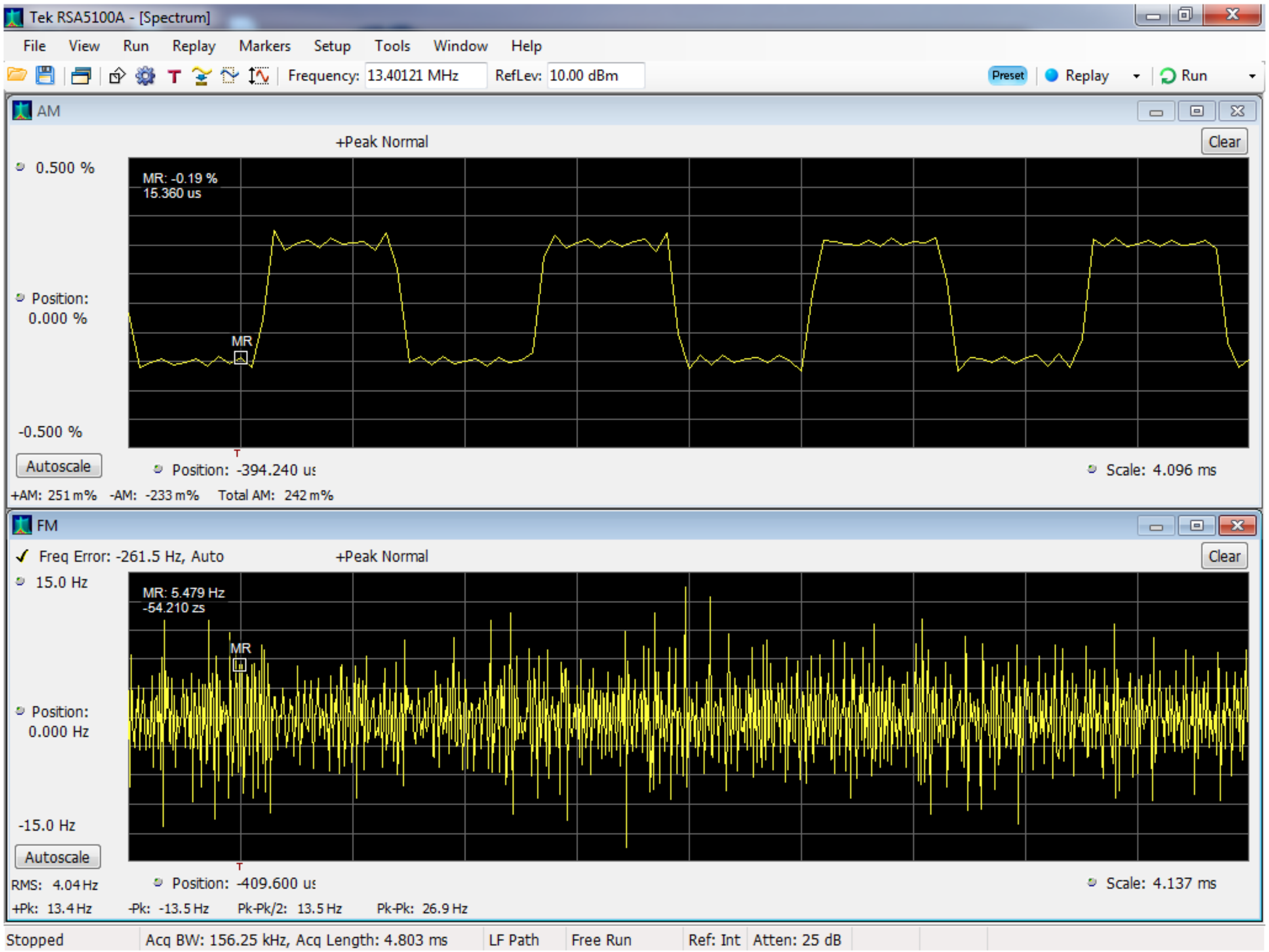

Figure 5 AWG set to 13.4MHz center frequency and 0.2% square wave modulation at 1kHz

In Figure 6 we can see that there is no evidence of the modulation signal in the AM window, while we can clearly see the modulation signal in the FM window. The corresponding phase noise results, also measured using the RSA5106A, for these two conditions are shown in Figures 7 and 8 respectively.

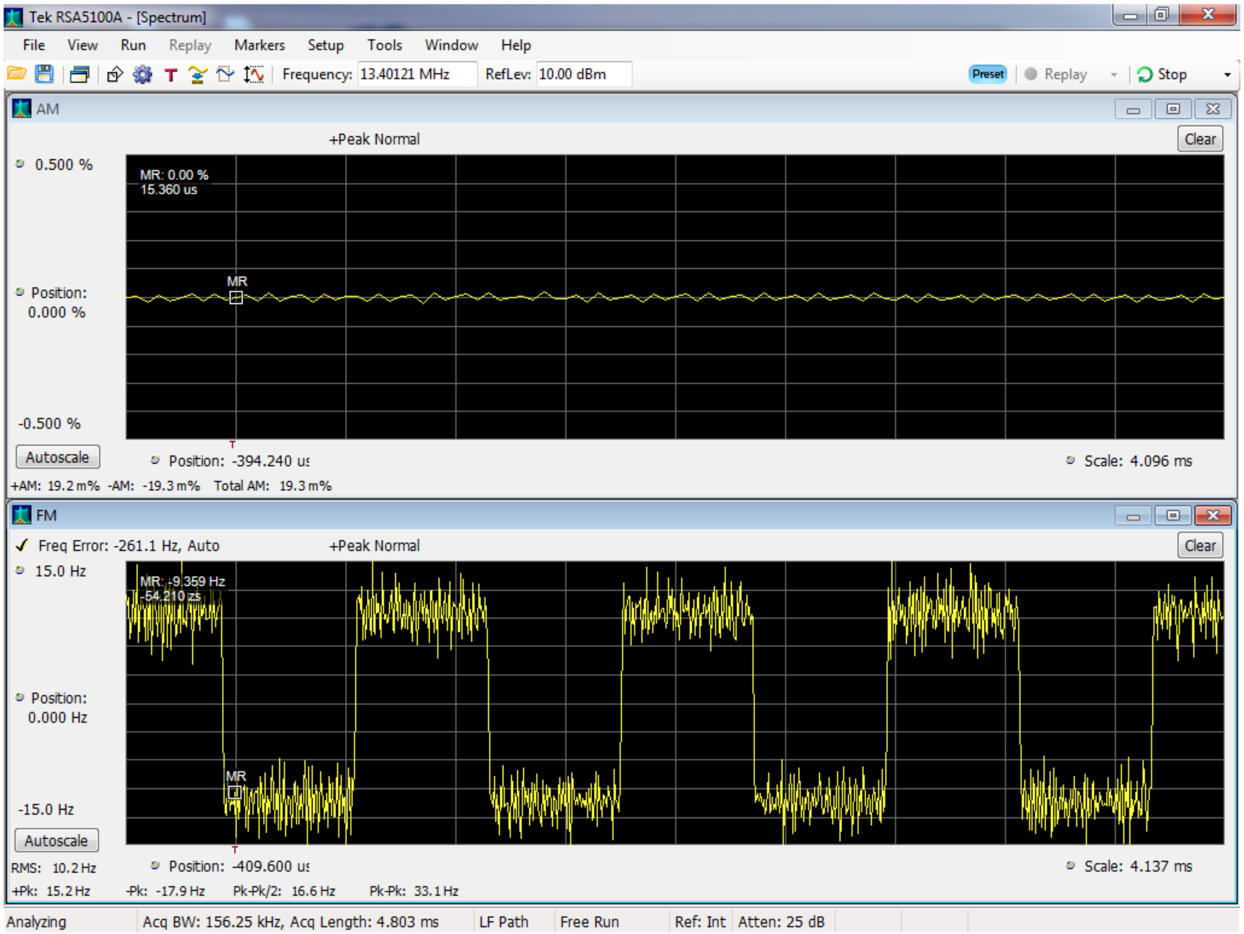

Figure 6 AWG set to 13.4MHz center frequency and 1kHz FM. Note that there is no evident AM and 1kHz square wave FM displayed.

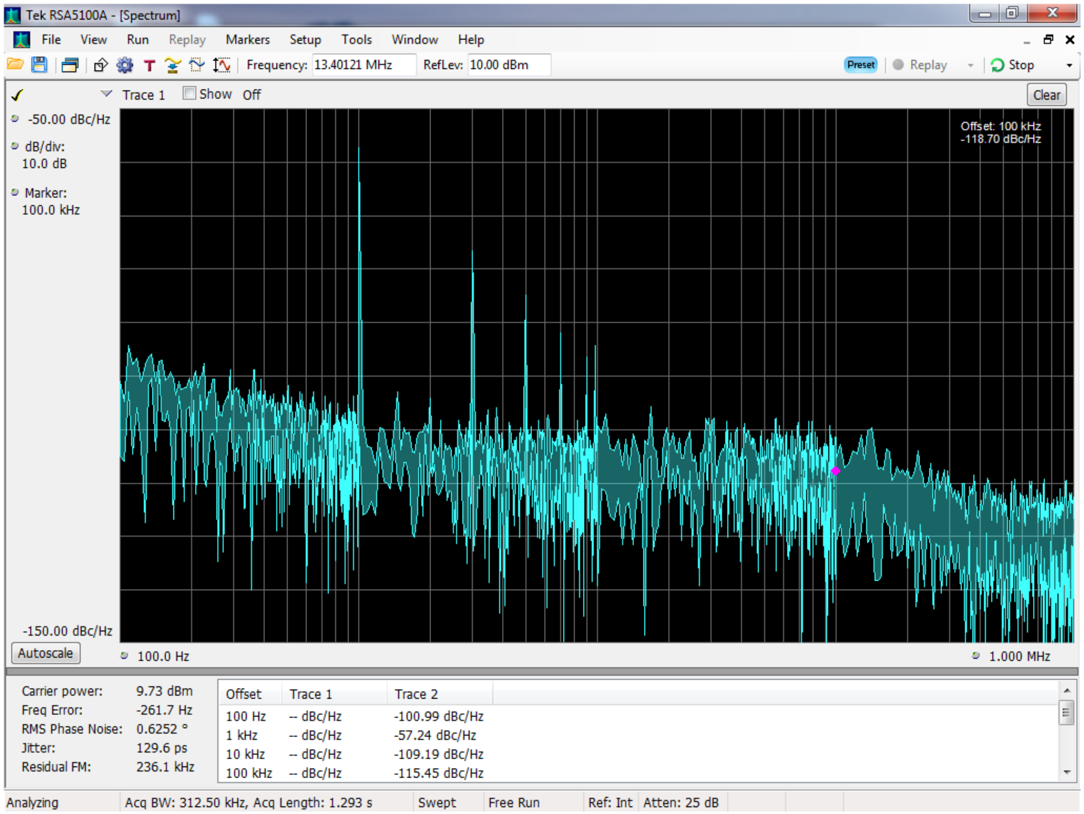

Figure 7 The phase noise with a 1kHz square wave FM modulation shows the 1kHz signal in addition to the odd harmonics, as expected for a square wave.

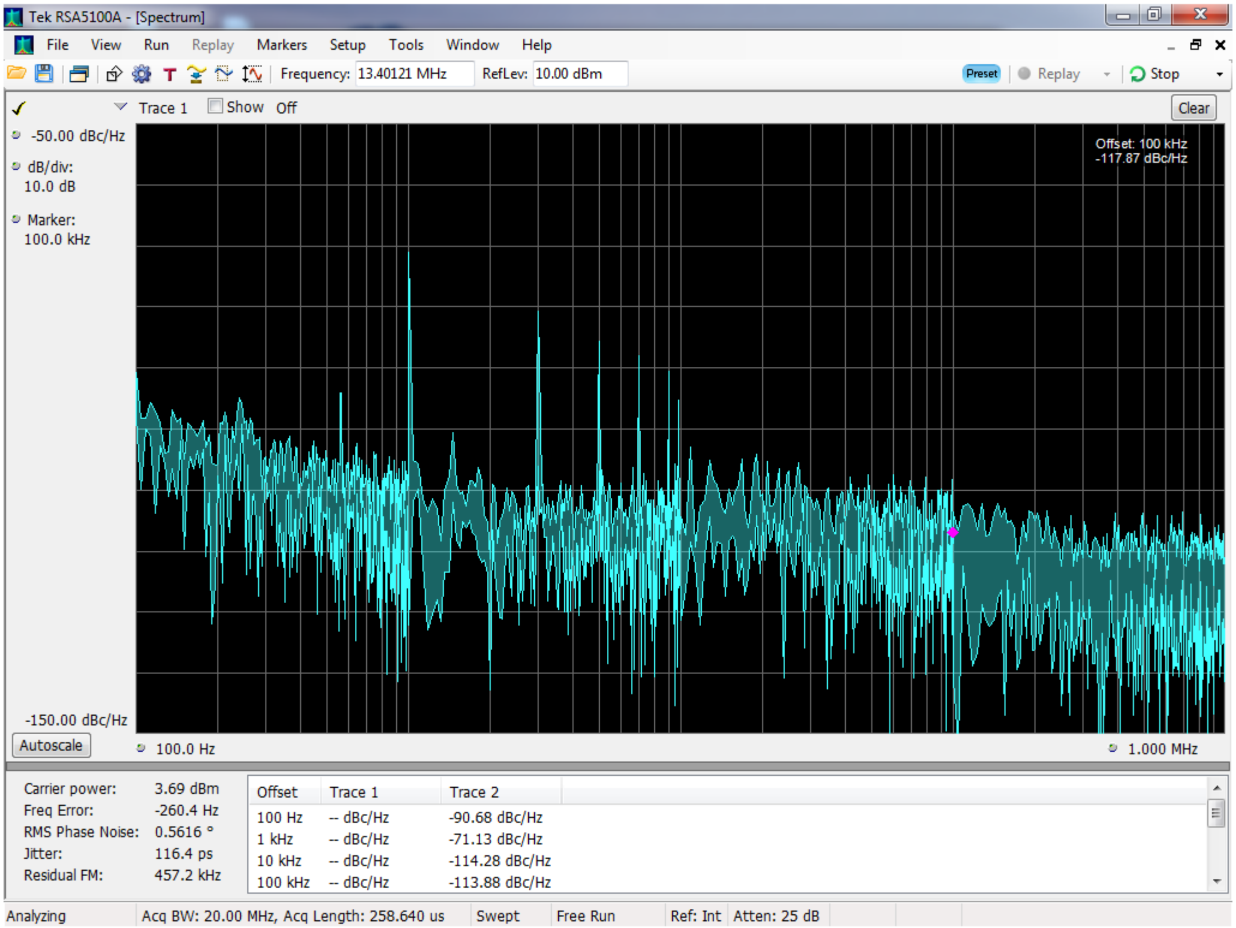

Figure 8 The phase noise with 0.2% 1kHz square wave AM modulation also shows the 1kHz signal in addition to the odd harmonics, as expected for a square wave.

Conclusion

The Tektronix RSA5106A along with the Picotest J2111A and J2130A Signal Injectors offer very simple, high fidelity measurement of clocks and oscillators, including clock PSRR and phase noise. The signal injectors allow the measurements to be made in an operating circuit, non-invasively, without loading the circuit and without breaking any connections.

The measurement results offer insight into AM and FM modulation effects either independently or combined.

The RSA5106A can directly measure phase noise of the oscillator, but the phase noise measurement alone does not provide an indication of whether the interference signal is the result of AM or FM modulation. This detail is essential in order to facilitate optimization of the clock performance.