Using the TI LMX2594 Synthesizer for Microwave Local Oscillators

Rick Fogle WA5TNY

If you have been involved in microwave experimentation for more than a decade then you probably remember the days of trying to generate a clean microwave local oscillator using a crystal oscillator in the VHF range and then multiplying it using various bipolar RF transistors. It was the only way to generate reasonably stable LO's but the downside was the difficult tuning of the stages and all the stages that also like to oscillate by themselves plus it was also impossible to lock them to a more stable reference when dealing with very low bandwidth signals (CW and SSB). There was available many versions of microwave surplus cavity oscillators that were locked to a VHF crystal operating around 100MHz and a high power cavity oscillator would drive a multiplier to output a multiple of the crystal but these too were tweeky and ran hot on usually -19 VDC at a lot of current and also were very microphonic. About a decade ago Hittite Microwave (now part of Analog Devices) came out with highly integrated synthesizers that contained the VCO, buffers and support circuitry to phase lock a low frequency reference signal using either integer N or fractional N dividers. They also integrated onto the IC the ability to divide the VCO output frequency to generate a very wide range of LO frequencies. Over the last few years there has been quite a few of these ICs developed and one of the latest synthesizer ICs is the Texas Instruments (TI) LMX2954.

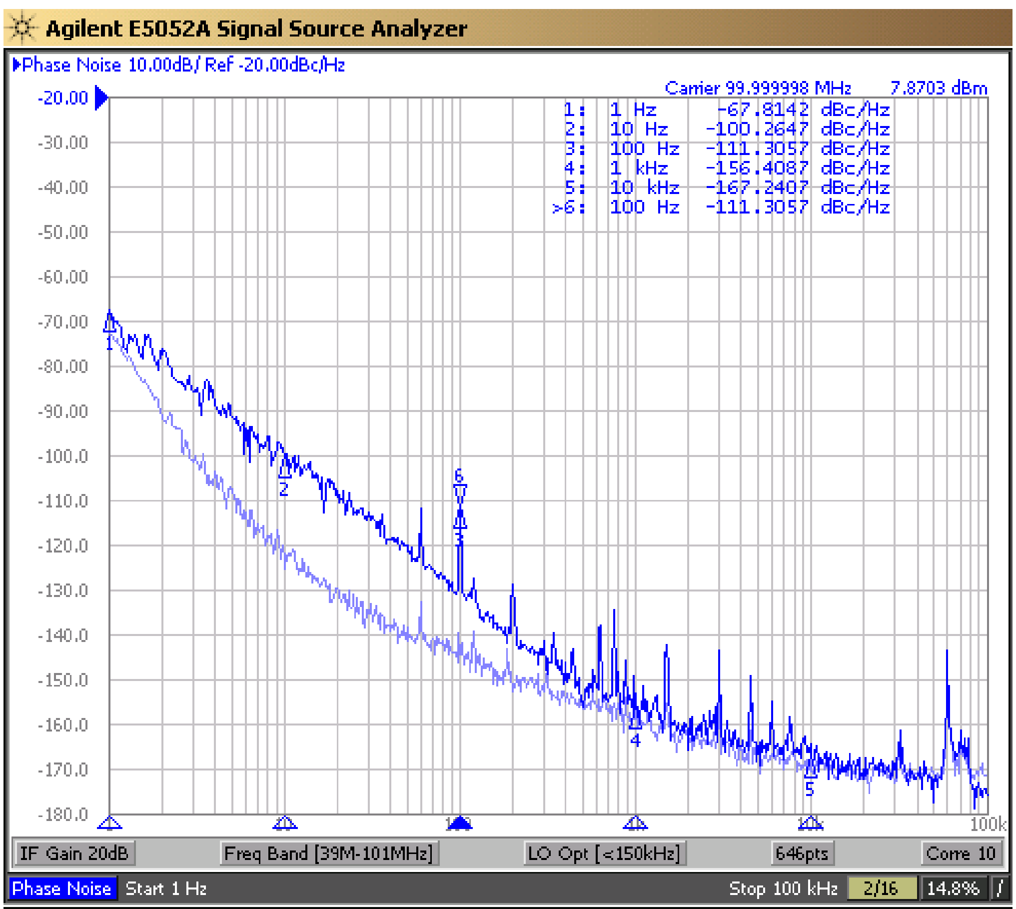
The LMX2954

This IC is a complete synthesizer on a chip, it includes almost everything needed to generate an LO from 10MHz to 15GHz with very good phase noise if a suitable reference oscillator is selected. The IC is very complex and its way beyond the scope of this paper to even touch on all the features but TI has an excellent set of technical documents available online and also offers an evaluation unit on a PC board with a USB interface for designers to easily fabricate a microwave LO. The evaluation board is easy to get operational but its not designed to incorporate inside your up or down converter unless you plan on connecting to a PC every time you power the unit up. The USB interface also contains a low phase 100MHz reference oscillator but this unit does not have the necessary stability to use for narrowband operation such a CW or SSB. While the evaluation board is fun to experiment with, in order to really use the device a new board needed to be designed with the ability to store the synthesizer register values so the unit would power up ready to be used, it can then be incorporated into portable equipment for field operation. For our application we interfaced the LMX2594 to a PIC microprocessor thru the SPI interface and then loaded a program via a JTAG interface where the PIC microprocessor would store the desired LO frequency and set up all the registers. Since the synthesizer requires a reasonably clean 3.3 VDC we also used the TI very low noise linear regulator which was driven by a wide input range switching power supply to improve the power supply efficiency and reduce the heat from dropping a large voltage across the linear regulator. The LMX2594 has internal low dropout regulators included with the IC but its still good practice to supply the IC and especially the reference oscillator with low noise DC linear regulators.

This can not be overstressed, the DC must be clean and free of any noise or it will degrade the overall synthesizer phase noise. The DC connection to the reference oscillator and LMX2594 should also be with short leads that are routed away from any switching power supplies or else you will start to see spurs at the switching frequency on the LO output. Its also not uncommon to see 60Hz and 120Hz low level spurs on unshielded LO’s as you will note in some of the following phase noise plots of the LMX2594 reference oscillators as the E5052A phase noise analyzer is capable of measuring extremely low levels of phase noise and spurs.

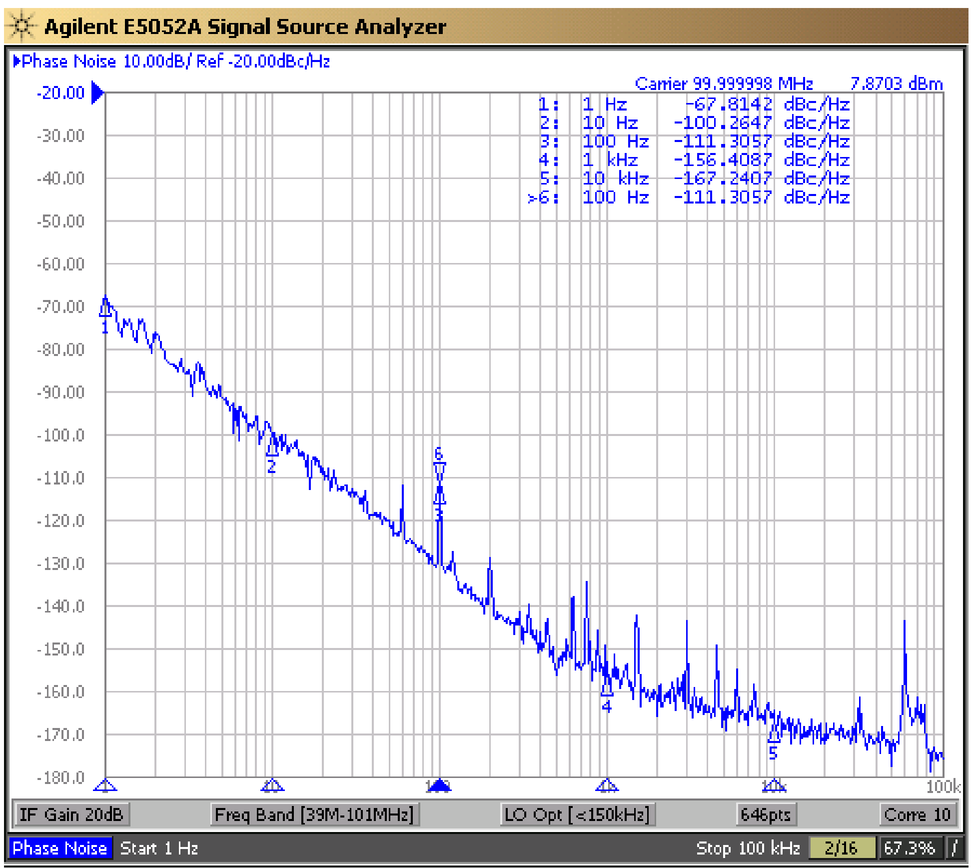
Reference Oscillators

Synthesizers are only as good as their reference oscillators. Synthesizers take on the phase noise characteristics of the reference oscillators phase noise in the loop bandwidth of the synthesizer but degraded at 20 Log Fout/Fref. As an example if we start with a 10MHz reference oscillator instead of a 100MHz reference oscillator we take a 20 Log 100MHz/10MHz or 20dB worse to start off with than if we started with a 100MHz reference oscillator. This is why these days most high performance microwave synthesizers start with a low phase noise 100MHz reference oscillator or at least higher than 10MHz to reduce the phase noise in the loop bandwidth at the output frequency. Typically the 100MHz phase noise reference oscillator won’t have as good as a 10MHz reference oscillator but its still better than starting with 10MHz unless you are synthesizing a low frequency LO.



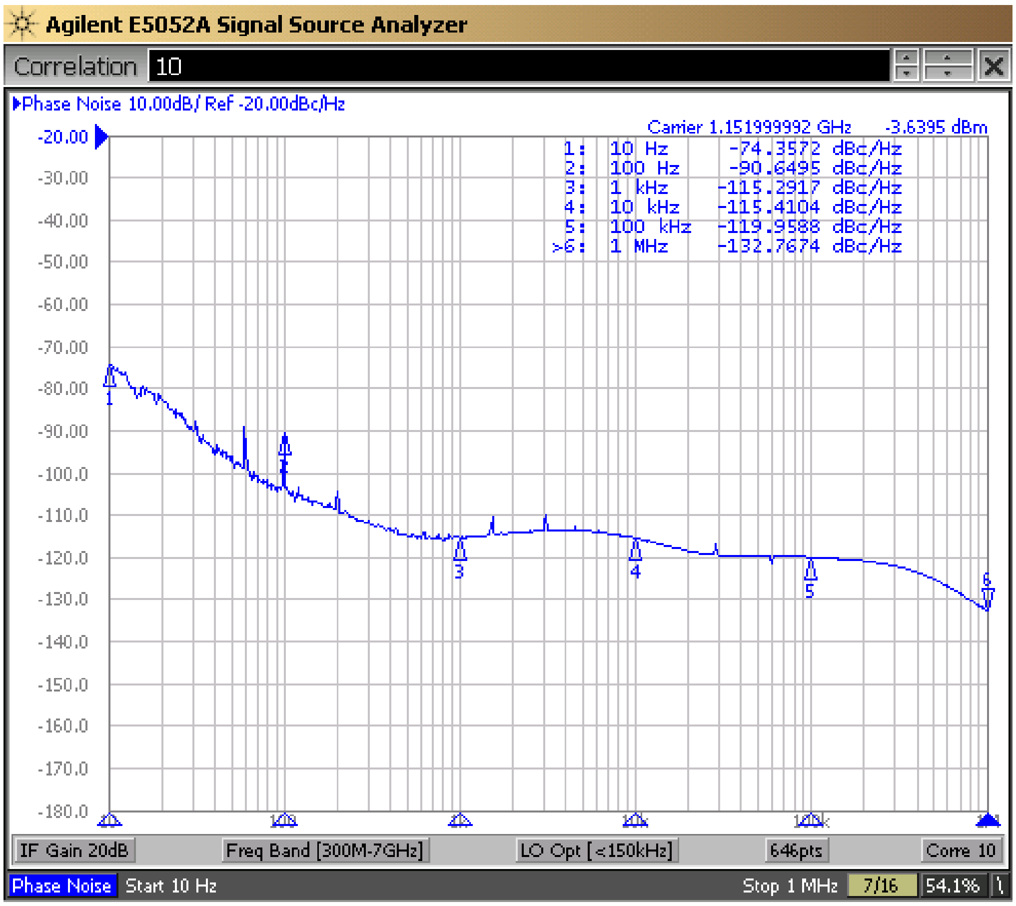
008 Plot 1 10MHz OCXO Reference Oscillator and 100MHz OCXO Reference Oscillator Compared Phase Noise

Plot 1 shows two reference oscillators, one at 10MHz and one at 100MHz. The lower phase noise plot is the 10MHz OCXO, the initial phase noise is about the same at 10Hz but the 100MHz is not as good until you reach around 1kHz. Remember that the 10MHz reference oscillator by the time its compared at 100MHz will degrade 20dB. These two oscillators are high performance OCXO units made by Wenzel Associates, the 100MHz OCXO during these tests was locked with a loop bandwidth of <5Hz to a 10MHz GPS reference as otherwise it could be off frequency as much as 10kHz, the 10MHz OCXO used in the test was not phase lock but was a free running OCXO. These are exceptionally good reference oscillators and are pricey but I do see them available along with other good oscillators available as surplus from time to time on Ebay.



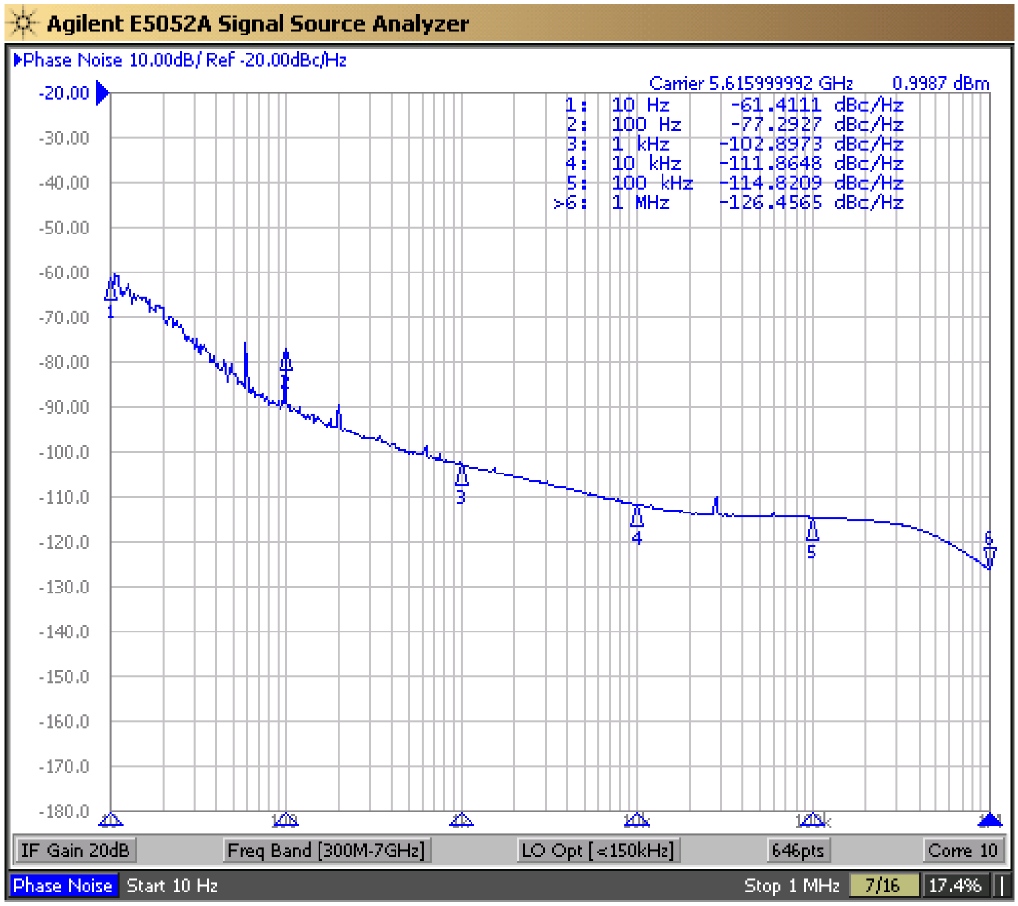
009 Plot 2 100MHz Wenzel Reference Oscillator locked to GPS 10MHz Reference Signal

Plot 2 Shows a good quality low phase noise OCXO that is locked to a GPS 10MHz reference signal with the GPS locking PLL with a loop bandwidth of about 5Hz. Most of the following phase noise plots use this reference oscillator to drive the LMX2594 Eval PCB using a single ended 50 ohm drive signal at about +6dBm.



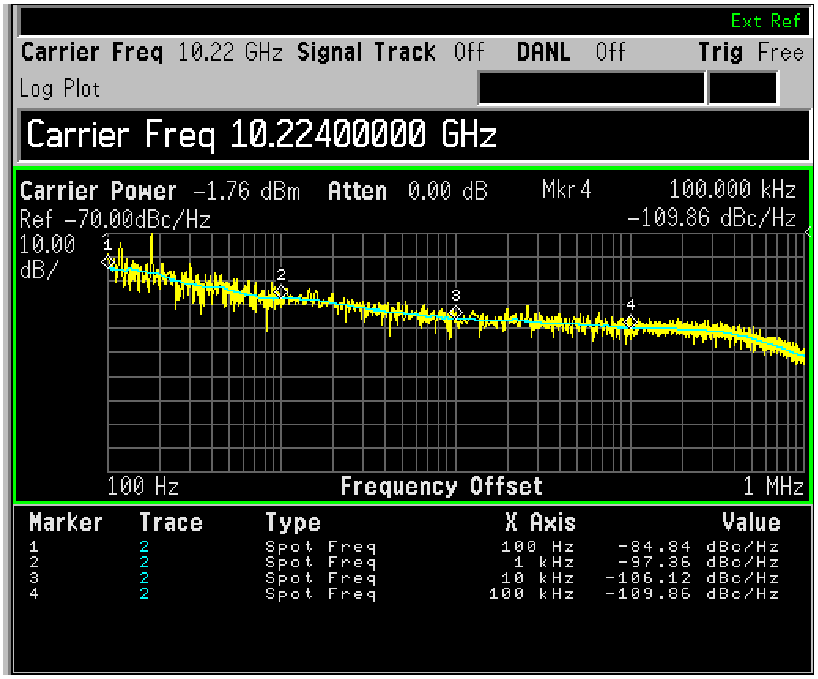
005 Plot 3 1152MHz LO for 1296MHz converter phase noise

Plot 3 shows the LMX2594 Eval board set up to generate an LO for a 1296MHz converter using a 144MHz IF difference. The LMX2594 VCO is operating at 9216MHz and the output is being divided down by 8 to the final 1152MHz. By dividing by 8 the actual oscillators phase noise is being improved by 20 Log 8 or 18dB. These phase noise values are pretty good for this type LO, only a phase locked DRO would be better.



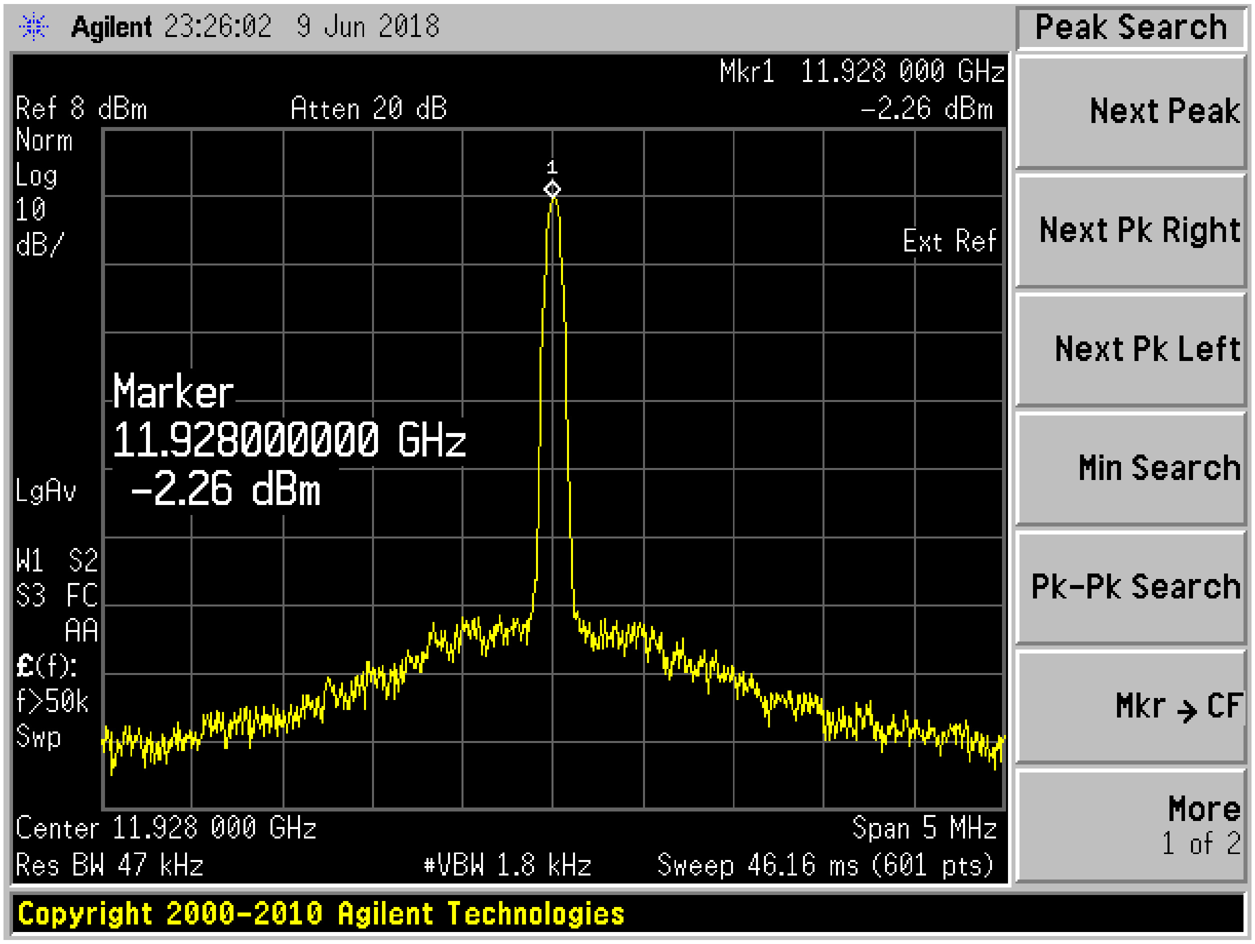
004 Plot 4 5616MHz LO for use with a 5760MHz transverter phase noise plot

Plot 4 shows the eval board reprogrammed to operate at 5616MHz using the 100MHz reference oscillator. The LMX2594 reference input frequency is being doubled by the IC to 200MHz and the phase detector is being operated at 200MHz. The LMX2594 VCO is operating at 11232MHz and the output has been programmed to divide the VCO frequency by 2. The phase noise is still very good, the output phase noise is being improved by 6dB by the divide by 2 on the output.

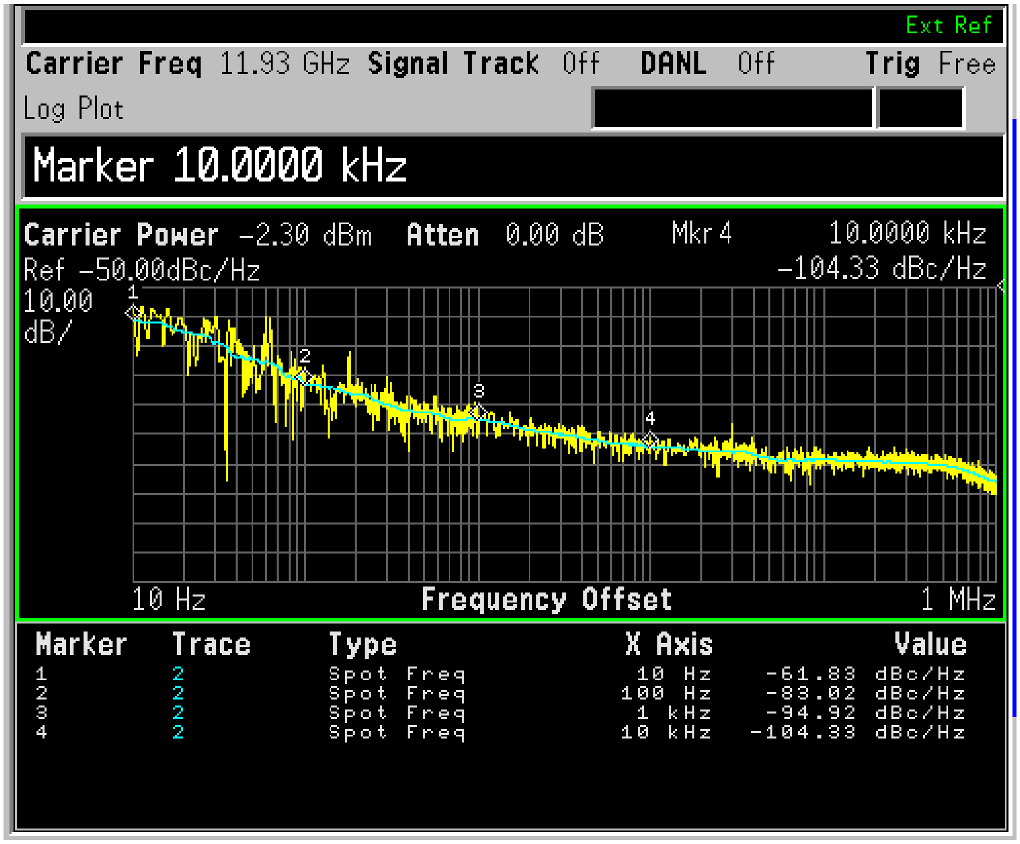


SCR513 10224MHz LO for 10368MHz transverter using a 144MHz IF

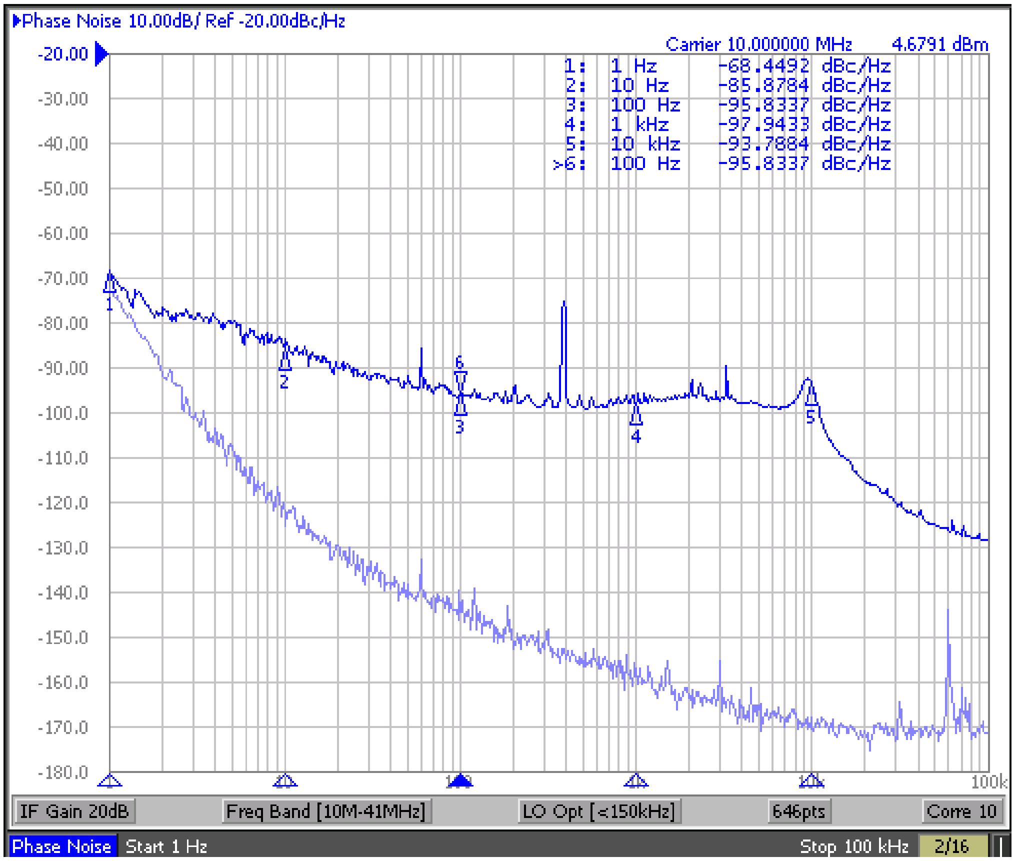
This phase noise plot is from a spectrum analyzer since the E5052A Signal Analyzer tops out at 7GHz. The phase noise plots using the spectrum analyzer will not be as accurate as the E5052A but are close enough to see the general trend in the LMX2594 as the LO frequency goes higher.



SCR514 Reprogrammed to generate a 11928MHz LO which can be used with a subharmonic mixer to make a 24GHz transverter. The LO operates at ½ frequency and is doubled in the subharmonic mixer, this alleviates the need to double the LO frequency before the mixer. Keep in mind that doubling the LO frequency in the subharmonic mixer will degrade the phase noise by 6dB from that shown on the plot.

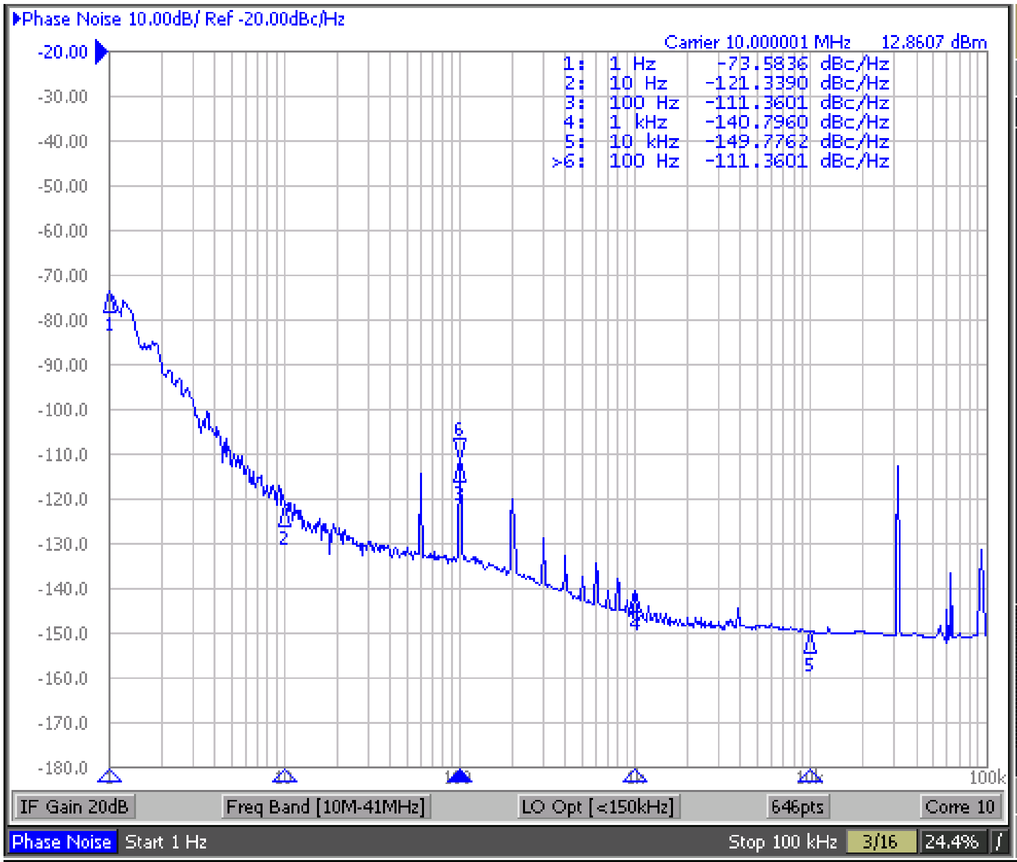


Scr 515 Phase noise plot for the 11928MHz LO



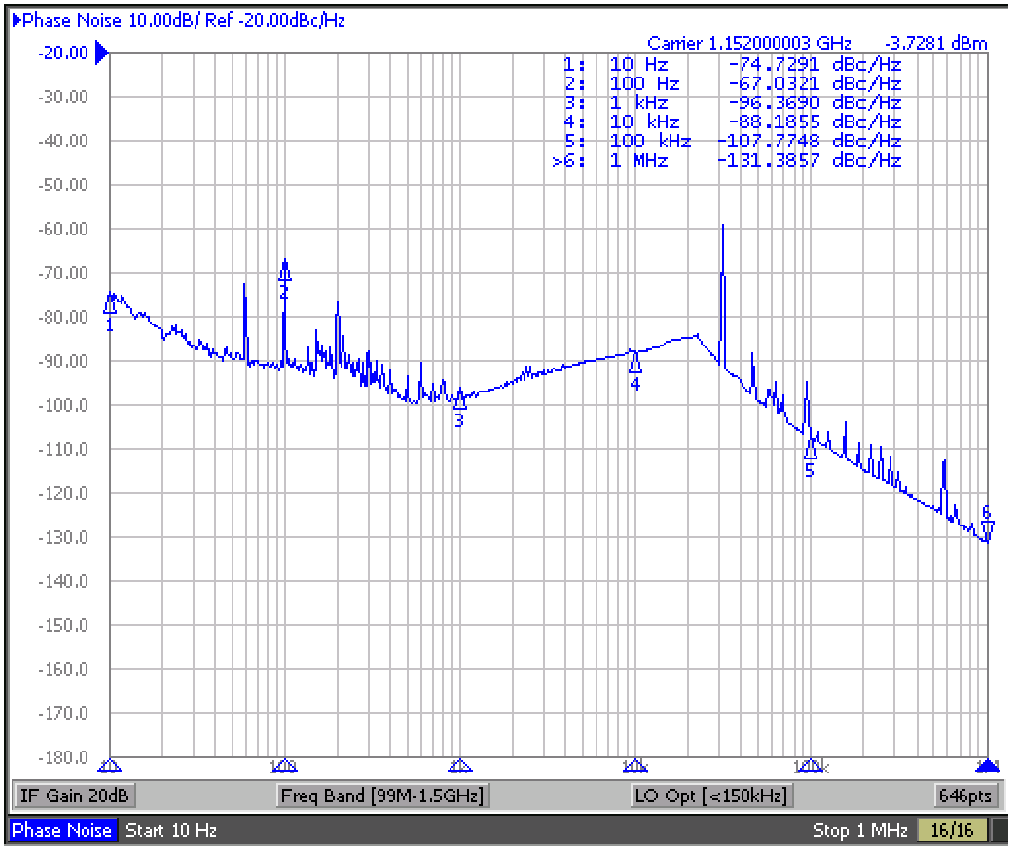
0010 Comparison of a Wenzel 10MHz free running OCXO vs 10MHz GPS phase noise

While making the measurements I decided to also show several extra plots of different oscillators and how they compared to each other. The plot above shows a Wenzel 10MHz OCXO free running reference oscillator (bottom trace) and a 10MHz output from a typical signal generator. This plot clearly shows why you never use a signal generator for a synthesizer reference unless just testing a circuit.

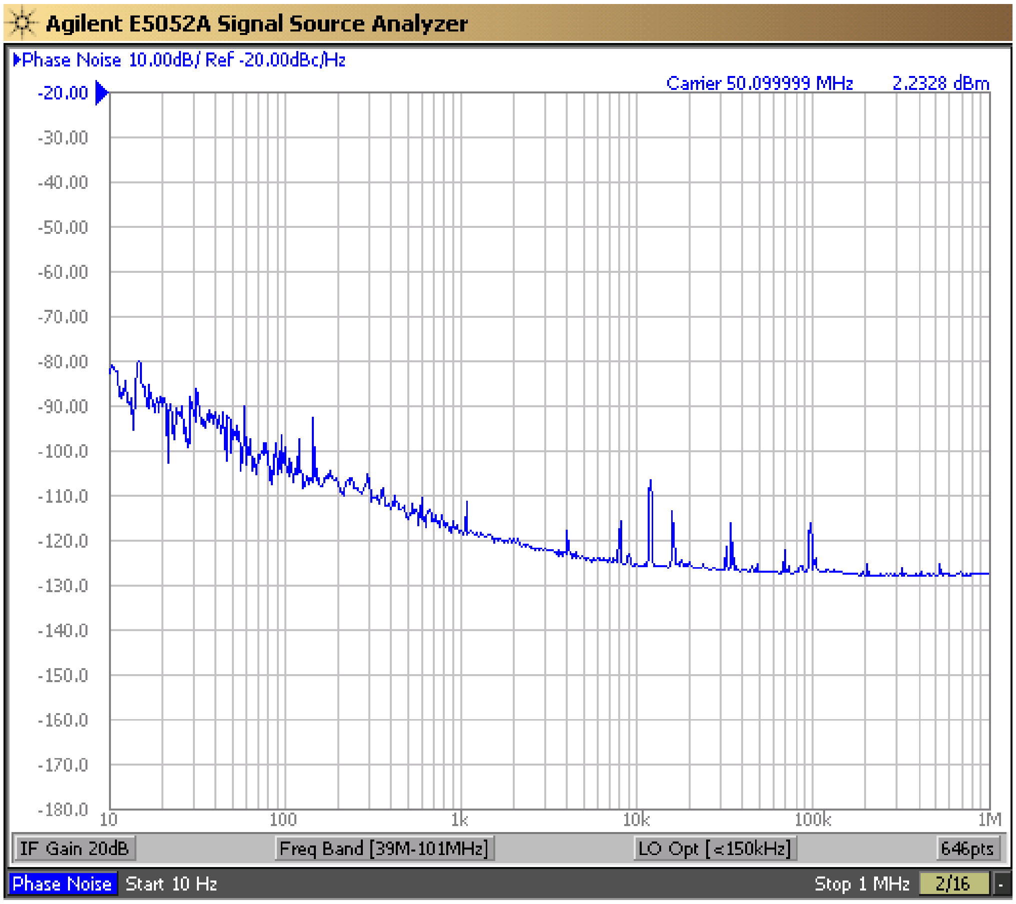


0013 Phase Noise plot of a typical 10MHz GPS reference signal used to lock a stations other oscillators.

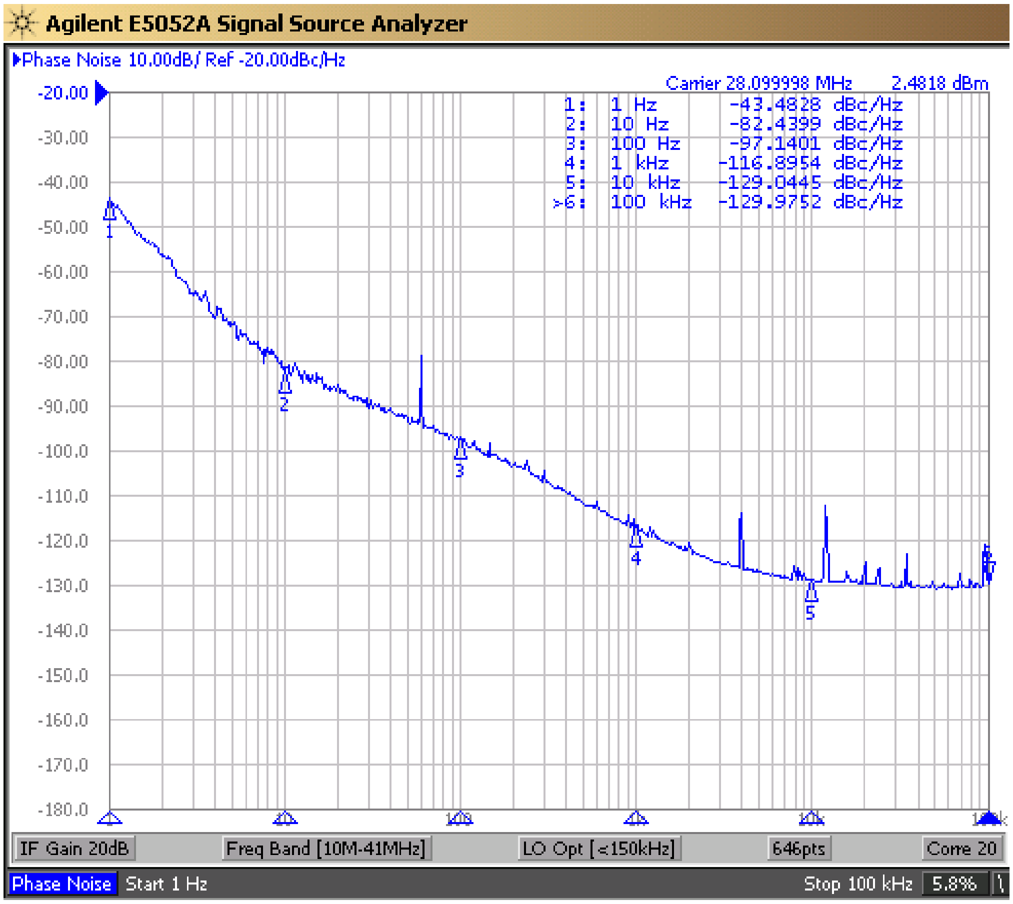
This plot shows the phase noise out of a typical GPS 10MHz disciplined reference signal that is distributed to other LO's to lock the frequency to a precision frequency reference. This signal is not intended to be used to as a synthesizer reference oscillator as I will show in the next plot. Most synthesizers that take an external 10MHz reference use a PLL with just a few Hz bandwidth to lock the frequency up but not to change the synthesizer phase noise, that is done by the local reference oscillator.



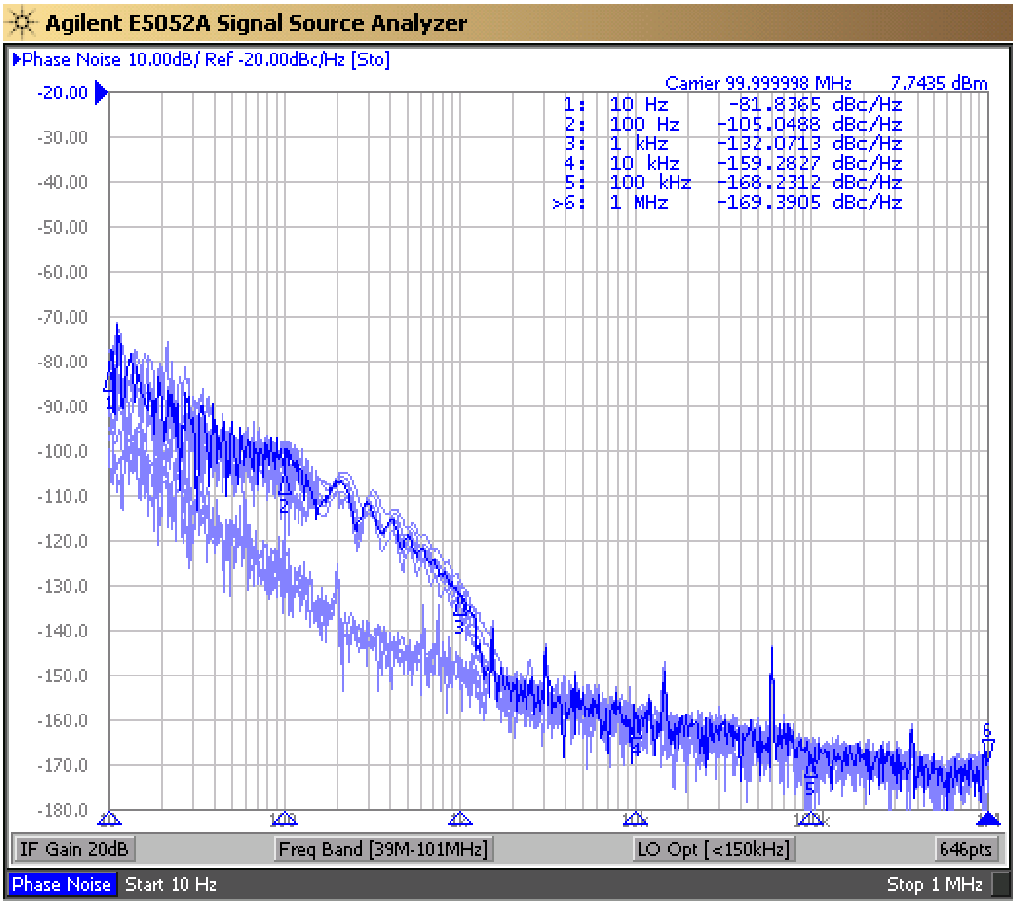
0015 1152MHz LO using the GPS 10MHz only as the reference oscillator. While this would probably work its certainly not a clean LO by todays standards.



ICOM-7300 Transceiver 10Hz to 1MHz phase noise 50.1MHz transmit frequency set to 20% power output with a 40dB power attenuator in line. These transceivers offer great performance and very clean signals as compared to the early radio synthesizers. Its good to keep in mind that this clean transmitter and receiver will be degraded if you mix these signals in a transverter with poor phase noise performance. Your mixed signals will take on the characteristics of the poor synthesizers phase noise.



ICOM-7300 Phase Noise 28.1MHz 20% power output CW. This plot extends from 1Hz to 100kHz.



Plot showing the 100MHz Reference Oscillator with light tapping on the case. Most reference oscillators are microphonic, usually much more so than the monolithic VCOs now used in the IC synthesizers. This plot shows the degradation between 10Hz and 2kHz of over 30dB due to mechanical vibration. When used as a reference oscillator in a microwave LO these hits can cause the synthesizer to unlock or at least cause the received signal in your transverter to sound awful. If you are really trying for the highest quality LO's you will probably need to shock mount at least the reference oscillator. Some oscillators are much more sensitive to vibration in one axis than the other due to the way the crystal is mounted. Reference oscillator vendors are becoming more aware of this and are working on oscillators that are less microphonic. Bliley has introduced some tiny TCXO's operating up to 50MHz that while not having as good phase noise performance of the best OCXO they are coming close to this performance with very low microphonics. Using one of these as a reference oscillator will give you around -95dBc/Hz performance at 10kHz offset at 5GHz.

The LMX2594 and other monolithic synthesizers are amazing devices as compared to the way we had to generate LO's even a decade ago. The designers have packed an fantastic amount of flexibility into these devices to lower the noise and coupled with a good reference oscillator, a small microprocessor and a clean DC supply today we can generate about any frequency desired with few spurious signals.