RF *cover story*

New Oscillators Advance the Art of Low Noise Performance

By Charles Wenzel
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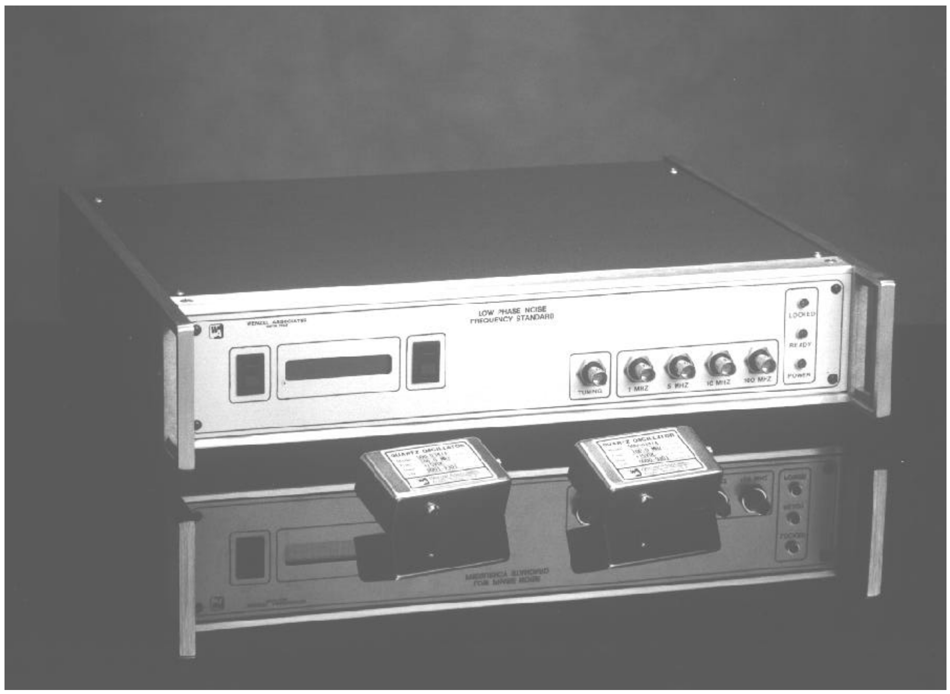
Over the last two decades, tremendous improvements in telecommunications, radar systems, and instrumentation have driven phase noise specifications from near obscurity to prime importance. Quartz crystal reference oscillators are especially crucial since oscillator noise often limits the channel capacity of communication systems, degrades the resolution of radar and timing instruments, gives synthesizers wide skirts and restricts the resolution of spectrum analyzers.



Wenzel Associates' new reference standard offers extremely low phase noise performance.

Wenzel Associates has developed new low noise oscillators with significant improvements in phase noise. In addition to a line of component VHF oscillators, a high stability frequency standard is available that employs phase locking to achieve excellent noise and long term aging. The phase noise performance of three, 100 MHz oscillators is shown in Figure 1.

Noise floor measurements near -180 dBc/Hz push the limits of ordinary phase noise measurement systems, so a phase noise calibration was requested of Fred Walls at the National Institute of Standards and Technology (NIST). His system uses a cross correlation technique to greatly reduce the system noise floor for measuring the higher Fourier frequencies. [This measurement technique will be described in the March 1993 issue of RF Design --- Editor] Fourier frequencies below 20 Hz were made using a multiplied 5 MHz reference. Each oscillator's noise data was fit to a mathematical model included in Figure 1. Overall measurement accuracy was stated to be ±1 dB between 1 Hz and 50 kHz.

Previous attempts to achieve low noise floors have employed drive levels reaching 50 mW in a brute force signal to noise battle with a corresponding degradation in close-in noise and aging. The unusual combination of a -180 dBc/Hz noise floor with a -77 dBc/Hz flicker frequency level is achieved by using low crystal dissipation (1 mw) in specially designed low noise circuitry. Careful attention was paid to voltage regulator noise and to oven current noise, two common sources of degraded performance. The oscillators' output level is set to 1 VRMS so the sideband noise at the floor is about 1.4 nanovolts/ $\sqrt{\text{Hz}}$ or about as much noise as exhibited by a 120 ohm resistor. Taking full advantage of such low noise levels poses a significant challenge to the systems engineer.

The model 500-03475 low phase noise frequency standard combines this new VHF oscillator with a similarly improved 5 MHz reference in a phase locked configuration. Figure 2 shows the phase noise for the standard's various output frequencies. The 5 MHz oscillator noise drops below -150 dBc/Hz 10 Hz away from the carrier and continues down to a floor of -180 dBc/Hz. The bandwidth of the internal phase locked loop is set to about 300 Hz where the 100 MHz oscillator begins to out perform the multiplied 5 MHz reference. The model 500-03475 employs a shielded

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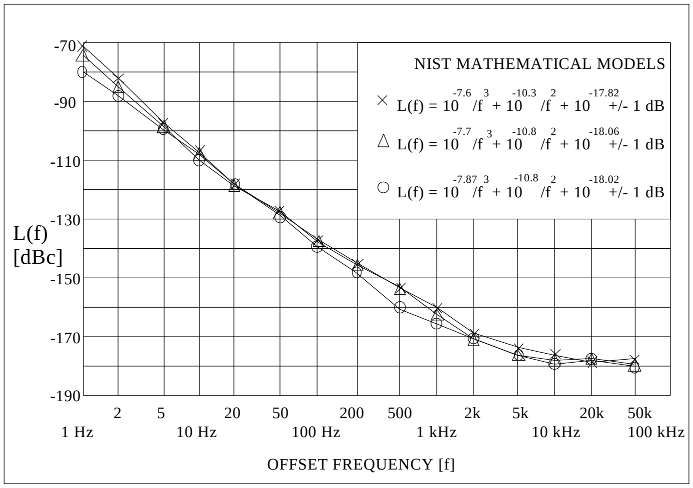

Figure 1. The phase noise of three oscillators measured by NIST.

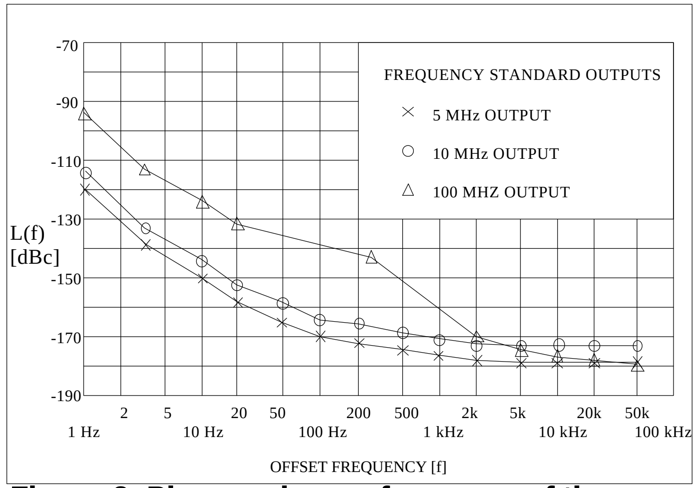

Figure 2. Phase noise performance of the 500-03475 Frequency Standard.

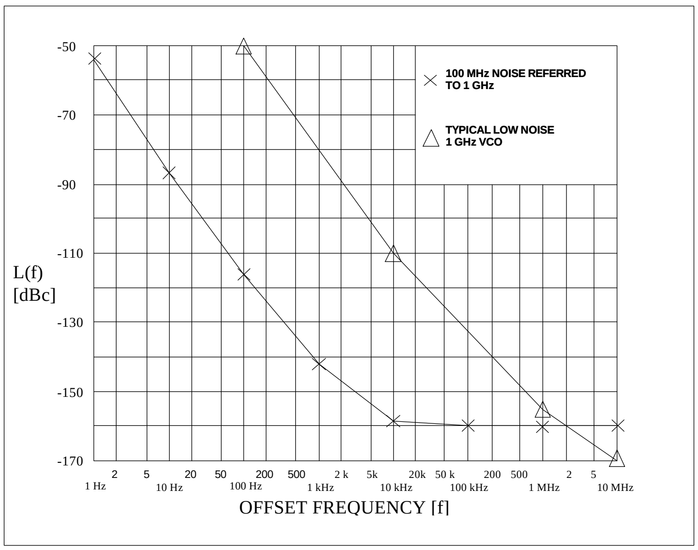

Figure 3. Comparison of a low noise VCO at 1 GHz to the multiplied 100 MHz oscillator.

line transformer to reduce line related noise in addition to a 10 hour rechargeable battery. Other features include digital monitoring of output levels and battery condition and digital control of tuning and aging rate.

High Performance Applications

Crystal oscillators with significantly improved phase noise can enhance a variety of systems. Microwave systems are particularly susceptible to reference oscillator phase noise because the process of frequency multiplication increases the power in the sidebands by the square of the multiplication factor. Phase locked loops or filters are often used to clean up the multiplied reference. In a typical system the filtering bandwidth is set near the point where the microwave oscillator's flicker noise drops below the reference oscillator's noise floor. With a reference noise floor of -180 dBc at 100 MHz an ideal x10 frequency multiplier would exhibit a noise floor of -160 dBc at 1 GHz, which rivals the noise floor of many microwave sources. Even after multiplication to 10 GHz the resulting -140 dBc floor would remain below the flicker noise of most VCOs out to several MHz. In some applications the VCO might be replaced by a simple filter to remove the subharmonics without any phase noise penalty. Figure 3 compares the new oscillator's noise, after multiplication, to an "ultra low noise" cavity oscillator operating at 1 GHz.

The combination of low flicker and low noise floor improves the bit error rate of a digital communication system for a given modulation scheme since the BER increases with the area under the phase noise curve. This small integrated noise or phase jitter similarly improves the resolution and probability of detection of radars and enhances the accuracy of distance measuring devices.

Modern spectrum analyzers using low noise synthesIzed local oscillators have improved sufficiently to allow for the direct observation of sideband noise of fairly good sources. A higher performance reference would lower than local oscillator noise even further, making smaller measurement bandwidths feasible for direct measurement of all but the best sources.

The electronics in these new oscillators is beginning to approach theoretical limits so future improvements will concentrate on the crystal resonators with a goal of lowering the flicker frequency level. Of course, improvements in temperature stability, aging, and other critical parameters will receive continued attention.

For more information on these low noise oscillators and frequency standard, contact the author at the address below, or circle Info/Card #160. *RF*

References

1. Fred L. Walls, "Calibration of 100 MHz crystal oscillators Model 500-02268B Serial #s 0578-9041 and 2110-9220 for Wenzel Associates," report by the National Measurement Laboratory, National I nstitute of Standards and Technology, Boulder, Colorado, 25 September 1992.
2. Addendum to above report, 6 November 1992.
3. Warren F. Walls, "Cross-Correlation Phase Noise Measurements," 46th Annual Symposium on Frequency Control, Hershey, PA, 1992.

About the Author

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