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Simple phase noise measurement

As the wireless industry moves towards systems employing more complex modulation - 8 PSK or HPSK, more complex spreading functions - IMT2000DS, IMT2000MC and higher performance requirements for existing technologies - GSM, GPRS, EDGE, the performance of receivers and transmitters (B/S and H/S) needs to improve to keep pace.

A fundamental component in any receive/transmit system, regardless of architecture is the oscillator. In receiver design, it is frequently the case that sensitivity and selectivity are limited by local oscillator quality, rather than the more traditional front end parameters of loss, gain, noise and intermodulation.

In the transmitter, phase accuracy and jitter parameters are being increasingly tightly specified so again oscillator(s) are in the spotlight. The usual oscillator design process is iterative, once the oscillator (crystal or VCO) is designed, additional engineering work is directed towards improving performance.

A fundamental parameter in the assessment of oscillator quality is phase noise. Accordingly the measurement of phase noise is an area much discussed by RF engineers and researched by test equipment companies. Many noise measuring systems are available and most good class spectrum analysers have an 'automatic' noise measuring facility, although this may be an optional fitment. These instruments are expensive but may be indispensable in the accurate quantisation and profiling of noise. However, as the oscillator noise optimisation process is usually progressed by a series of small steps it can tie up this expensive test equipment for long periods of time while examining this one parameter.

This article is intended to show two methods of noise measurement that can be used at low cost to give accurate relative measurements so that the engineer can assess if any particular design change yields a step forward or back.

Method One

In this method it is not necessary to use a separate reference oscillator. The only input to the system is the oscillator to be analysed.

The oscillator output is applied to an in-phase divider, one output port of the divider goes to the LO of a mixer, the other output port passes through a delay line to the RF port of the mixer.

The two signals applied to the mixer produce a voltage at the IF port that is dependent on the phase difference between them. The volts are negative when the signals are in phase, zero when they are 90° out of phase and positive volts when they are 180° out of phase.

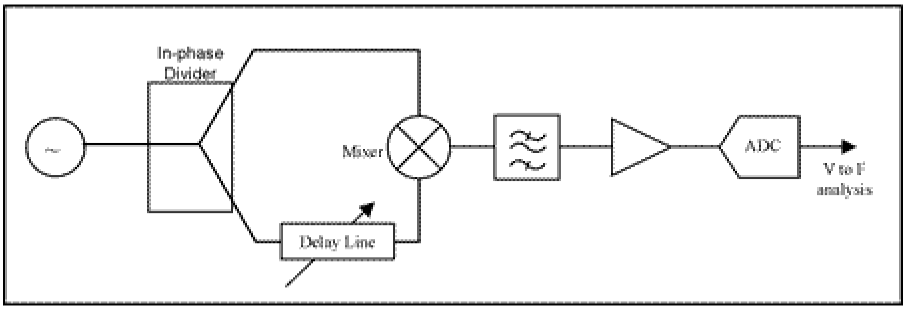
If the delay line (length) is set so that the signals have a quadrature phase difference the IF signal will be zero volts with an AC signal superimposed whose amplitude is proportional to the frequency/phase noise of the oscillator.

The mixer output at baseband can be digitised, ie sampled in an ADC and then analysed for its volts versus frequency characteristic.

The length of the delay (line) determines the system's ability to convert frequency noise to voltage noise. The longer the line, the greater the rate of change of output voltage with input frequency at the zero crossing point, ie the system is more sensitive. However, delay line attenuation must be controlled as loss of signal reduces the mixer input port signal and hence reduces IF output.

The advantage of this system is that it is applicable to VCO's without the requirement of placing the VCO in a phase lock loop (PLL) to stabilise it. The PLL noise output is a composite effect of the loop components/characteristic and the VCO itself, so further analysis would be necessary to separate out the VCO noise.

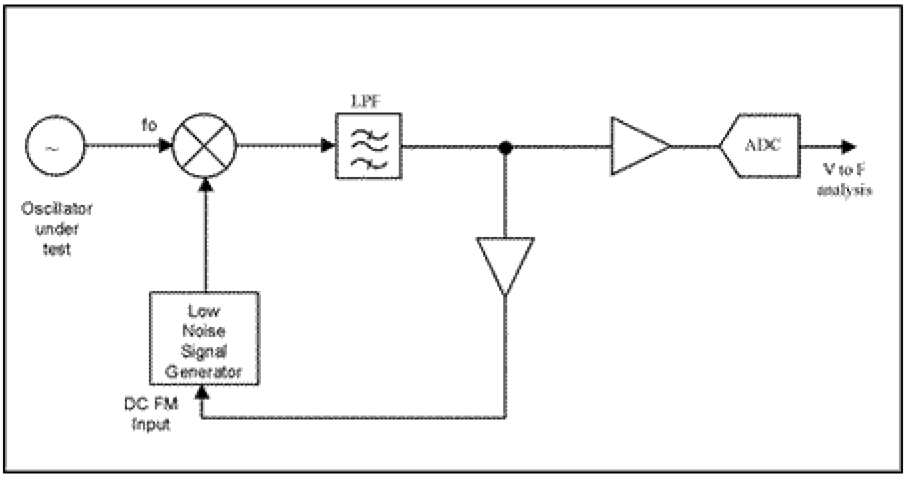
Interestingly, the same configuration (less the post mixer analysis) as described for measuring phase noise can be used to reduce it. Again, if the signal (fo) is split into two paths, one directly to the mixer and one through a long delay line to the mixer an output of twice fo is obtained. Due to the long delay (t), the noise sidebands do not recorrelate in time (phase) at the mixer input, so that on mixing the noise uplift is only 3 dB, not 6 dB as occurs in direct frequency multiplication (doubling). The improvement of 3 dB occurs for offsets greater than 1/t. The final stage in the process is to divide the 2fo obtained to recover the original fo.



Method Two

An alternative 'measure' of phase noise requires a low noise signal generator (at the frequency to be measured) with a DC FM capability, a phase detector (mixer), a simple low pass filter and some form of audio analysis or audio power measurement. The oscillator (or multiplier) to be characterised is input to one mixer port and the signal generator output to the other. The mixer output is passed through a simple low pass filter - an R and C are sufficient. The filter output is then amplified (if necessary) and fed to the DC FM input of the signal generator. The audio analysis is made on the signal recovered at the output of the filter. This measurement system can be employed simply as described, where a simple type 2 phase lock loop is formed, as a relative indicator of oscillators under test. The phase lock loop maintains phase quadrature between the two signals at the phase detector. The signal generator noise characteristic must be much better than the device under test.

The method may be extended to quantify and analyse in detail oscillators having noise characteristics down to -160 dBc/Hz, but rigorous low noise procedures must be followed including low noise power supplies and a high degree of shielding/isolation to prevent injection locking. Calibration is also required at the offset frequency at which the oscillator under test is to be characterised.



Note, in both methods the baseband analysis may be replaced by a simple voltmeter (preferably calibrated in dBs, although not essential) for a useful relative indication of noise improvements.

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geoff@rttonline.com

00 44 208 744 3163