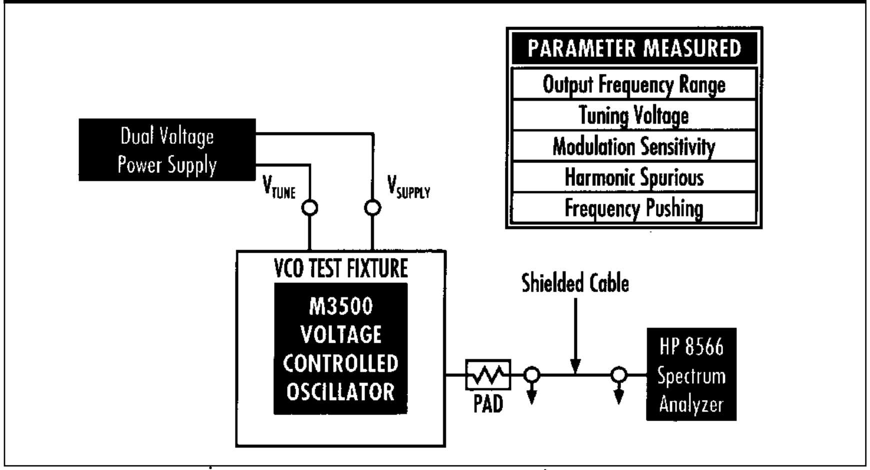
TEST METHODOLOGY

TEST CONFIGURATION 1



TEST CONFIGURATIONAND PERFORMANCE

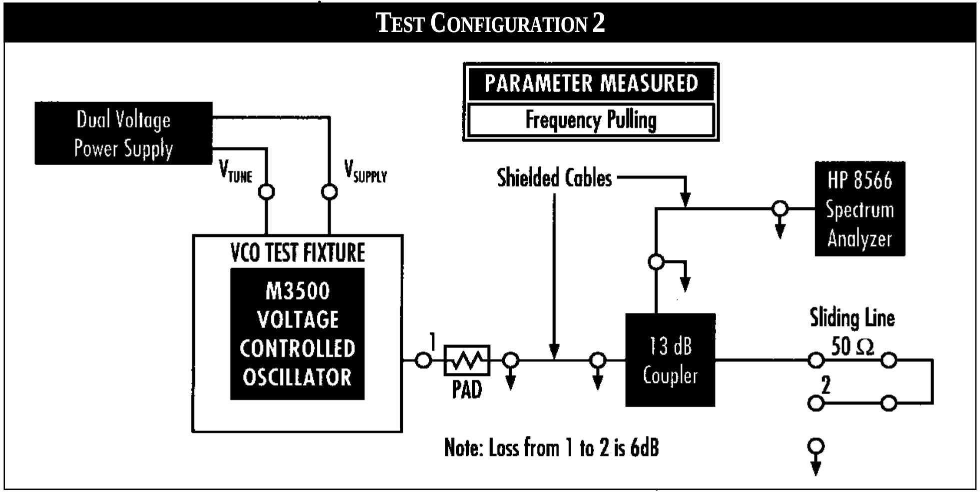
Test Configurations 1,2,3 & 4 illustrate the actual test methods used for collecting the test data for all M3500 VCO versions.

The performance curves of figures 2 A-M (pages 9-22) were generated using Test Configuration 1. The Frequency vs. Voltage curve values are used to compute modulation sensitivity. The Frequency Pushing value is determined by collecting the Frequency vs. Voltage curves at the nominal supply voltage values ± 1 VDC and extracting the typical frequency variation shown in tables 1 A-M (pages 9-22), which depict the absolute Maximum/Minimum, Guaranteed and Typical performance characteristics.

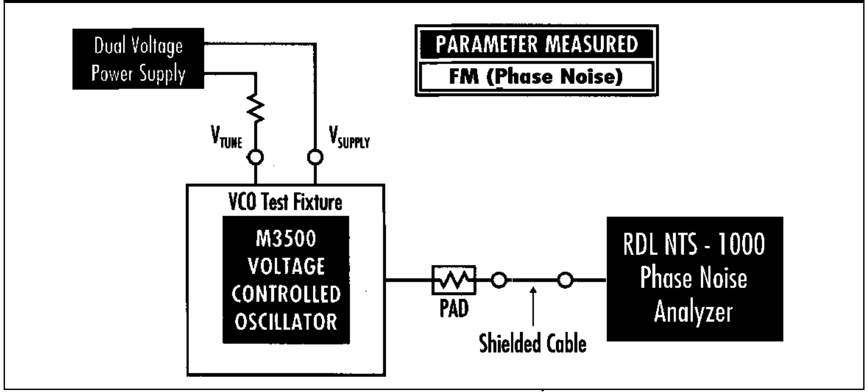
The Frequency Pulling values are collected using Test Configuration 2. The Sliding Line was shifted from 0 to 360° through the full output frequency range of each VCO version. The typical peak-to-peak variations are shown in tables 1 A-M.

The Phase Noise performance was determined by measurement of the output spectrum of the VCO on the RDL NTS 1000 Phase Noise Test System, capable of precision measurements down to -160 dBc/Hz (Test Configuration 3).

TEST CONFIGURATION 2



TEST CONFIGURATION 3



The values of phase noise at offsets of 1, 10, 100 & 1000 kHz are shown in tables 1 A-M.

The Tuning Port Bandwidth values were determined using Test Configuration 4. In order to determine the frequency modulating bandwidth of the VCO's tuning port, precise phase adjustment for different tuning voltages within its frequency range is required. For this reason, the Sliding 50Ω Line is employed to allow accurate phase setting into the mixer/detector over the complete output range.

PHASE NOISE AND RESIDUAL FM DEVIATION

One way to view phase noise is the contribution of unwanted signals or noise that randomly modulates the fundamental carrier frequency. As concerning the VCO, this is generally determined by the aggregate affect of the following:

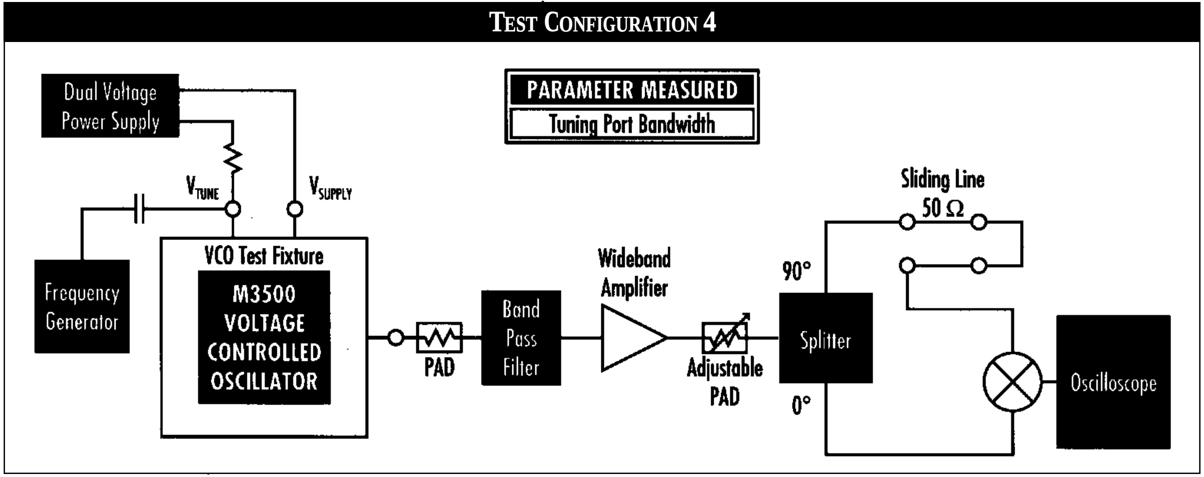
a) Sources of noise from the semiconductor physics within the device such as flicker noise (1/f), shot noise and thermal noise.

b) Component limitations such as the finite Q of the tank circuit, leakage effects, etc.

c) Externally-induced factors such as inadequate ground contact, microphonic pick-up, or insufficient isolation of the power supply and radiating signal sources.

When the energy of a desired signal appears only at the desired frequency, phase noise is considered perfect and

TEST CONFIGURATION 4



would consist of a single spectral line of infinitesimal width. As this panacea changes into the real world, we find the typical noise floor landscape of the VCO's output having a relatively high noise density very close to the carrier and tapering off symmetrically away from the carrier. Another way of defining the above-mentioned affects is to convert the single sideband power level to an equivalent frequency deviation that would produce the same noise density at the same frequency offset from the carrier. This relationship is determined by the following equation:

$$20\ \text{LOG}\left[\frac{2\ f_{SSB}}{f_{DEV}}\right] = \text{dBc}$$

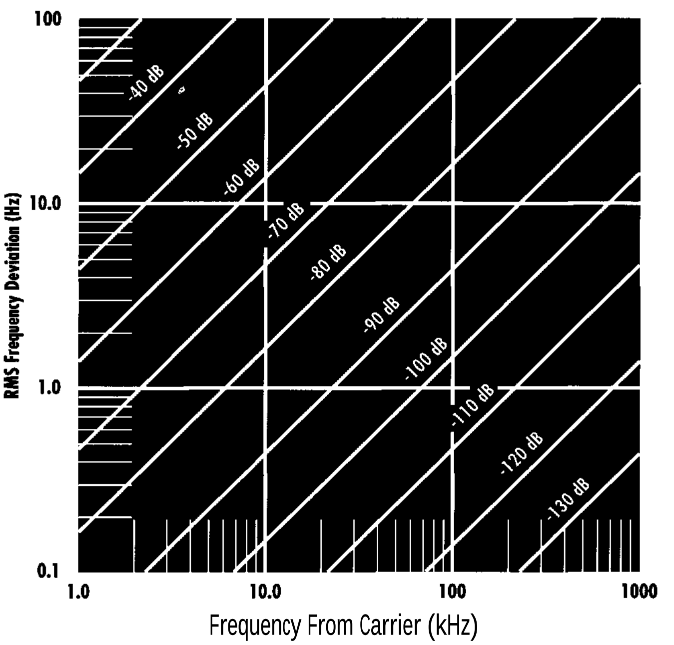
where:

f_{SSB} = frequency offset from carrier where single sideband power level is given.

f_{DEV} = equivalent frequency deviation (peak) that would produce the same noise level in a 1 Hz bandwidth at the same frequency offset from carrier.

dBc = the level of the dBs below the carrier where phase noise at a given frequency offset is specified.

FIGURE 1. PHASE NOISE CONVERSION NOMOGRAPH



For example, the M3500-0612 VCO specifications state that the single sideband phase noise is - 94dBc/Hz at a frequency offset of 10 kHz. Rewriting from the above equation yields the following:

$$20\ \text{LOG}\left[\frac{2\ (10\ \text{kHz})}{f_{DEV}}\right] = 94\text{dB}$$

$$\text{INV}_{\text{LOG}}\left[\frac{94}{20}\right] = \frac{20 \times 10^{3}}{f_{DEV}}$$

$$f_{DEV} = 0.4\ \text{Hz Peak}$$

$$\frac{f_{DEV}}{\sqrt{2}} = 0.4\ \text{Hz Peak}$$

A frequency deviation of 0.28 Hz RMS equates to a single sideband phase noise of -94 dBc/Hz at a 10 kHz offset frequency. Figure 1 is provided as a convenient nomograph to convert between the two definitions.

As tables 1 A-M (pages 9-22) indicate, the M3500 series has low phase noise. However, overall system phase noise is more subtle than just the sum of the VCO, reference, loop filter and phase detector's individual phase noise contributions.

At different offsets from the carrier, one part of the loop will dominate in contributing phase noise. This depends on the loop's natural frequency, which in turn depends on K_V, the VCO modulation sensitivity (measured in MHz/V). If K_V were linear, then loop design and phase noise analysis would be straight forward. Unfortunately, based on extensive testing performed at QUALCOMM, a typical VCO's K_V is non-linear, with K_V decreasing with increasing frequencies as depicted in Figure 2.

QUALCOMM specifically engineered these VCOs to optimize K_V as depicted in Figure 3. This greatly eases PLL gain normalization over the full tuning range for improved stability (phase margin), settling time, and improved close-in system phase noise which, in turn, eliminates any need for gain normalization circuitry.

Figure 2. VCO Non-Linear K_V Example

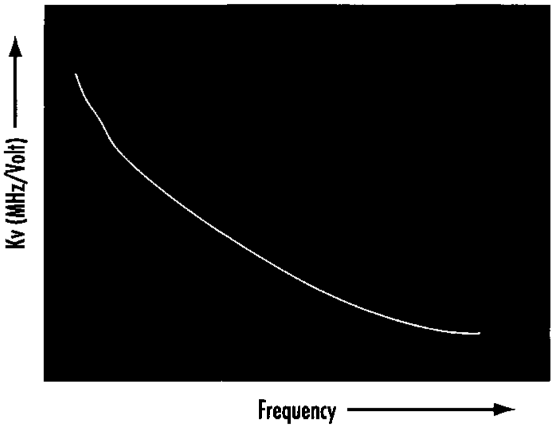
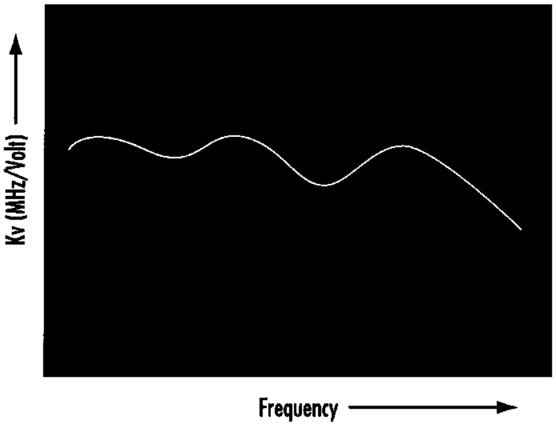


Figure 3. M3500 Optimized K_V Example



As a result, the PLL loop bandwidth (ideally, the frequency where VCO phase noise, and the multiplied-up reference phase noise are equal) in a synthesizer using the M3500 will be more constant and will have a lower overall system phase noise than the same system with a VCO whose K_V behaves differently.