APPLICATION NOTE #3

Phase Noise Measurement of Pulsed CW Signals

1 INTRODUCTION

Phase noise measurements of pulsed CW signals requires some modification of technique when compared with pure continuous wave signals. First, the average power of a pulsed CW signal is reduced as a direct function of the duty cycle. Secondly, the asymmetric duty cycle introduces a DC component which appears as a DC offset at the phase detector output when the quadrature phase lock method of phase noise measurement is employed. Further, transients are introduced at the leading and trailing edges of the pulse envelope. These characteristics of a pulsed CW signal can make phase noise measurement problematical unless the measurement system is carefully designed to mitigate the difficulties.

Since the highest quality phase noise measurements are achieved using the quadrature phase locked loop method, and since pulsed CW signals often require the most stringent phase noise specifications, we restrict our discussion to this measurement technique. The Aeroflex Comstron PN9000 Phase Noise Measurement System is designed to make precision pulsed CW phase noise measurements using the quadrature phase locked loop method.

Power reduction associated with duty cycle is corrected in the PN9000 software. DC offset and transients are accommodated in the PN9000 by an Operational Low Noise Amplifier following the phase detector. This amplifier supports a large output voltage swing which greatly reduces the amplifiers tendency to saturate, a common malady of LNAs. Also, appropriate filtering is provided between the phase detector and the LNA in order to reduce the effect of transients.

These characteristics of the pulsed CW signal and the associated signal power reduction dictate that the parameters of the quadrature loop can be set with these factors taken into account. In particular, the loop bandwidth, phase detector calibration, and phase locking must be set commensurate with the particular characteristics of the pulsed CW signal.

These considerations are discussed below.

2 COMPENSATION FOR POWER REDUCTION

Average power reduction, which is directly proportional to the duty cycle of a pulsed CW signal, manifests itself as desensitization of the phase detector. The phase noise detected decreases proportionally as the duty cycle. This is expressed in dB as 20 log D (D = duty cycle expressed in proportion).

e.g. D = 0.1, 20 log (0.1) = -20 dB.

The PN9000 accounts for this by means of an entry its Calibration menu designated Pulse. When this function is chosen, the PRF of the DUT signal is entered and the software automatically computes the required compensation and corrects the data. Also the gain of the phase locked loop is automatically adjusted to maintain the correct loop bandwidth as in pure CW measurements. These processes make the measurement easy to perform.

3 DC OFFSET AND TRANSIENTS

Most Low Noise Amplifiers cannot handle offset signals and are prone to saturation especially when transients and/or offsets are present. The Aeroflex Comstron PN9000 uses a proprietary Very Low Noise Operational Amplifier with an output swing of ± 5 volts. This swing supports the vast majority of practical measurement cases.

The PN9000 also provides three filters for PRF filtering. These are factory set to support PRF requirements requested by the user. Additional filtering can also be implemented by the user.

4 PHASE LOCKED LOOP BANDWIDTH

The phase locked loop bandwidth should be adjusted so that it does not exceed 1/20 of the PRF of the DUT. For example, if the PRF is 10 kHz, The maximum loop bandwidth is 500 Hz.

5 PHASE DETECTOR CALIBRATION

For accurate measurements calibration is presently done in CW mode. The PN9000 will incorporate a special calibration process for Pulsed CW mode in the future.

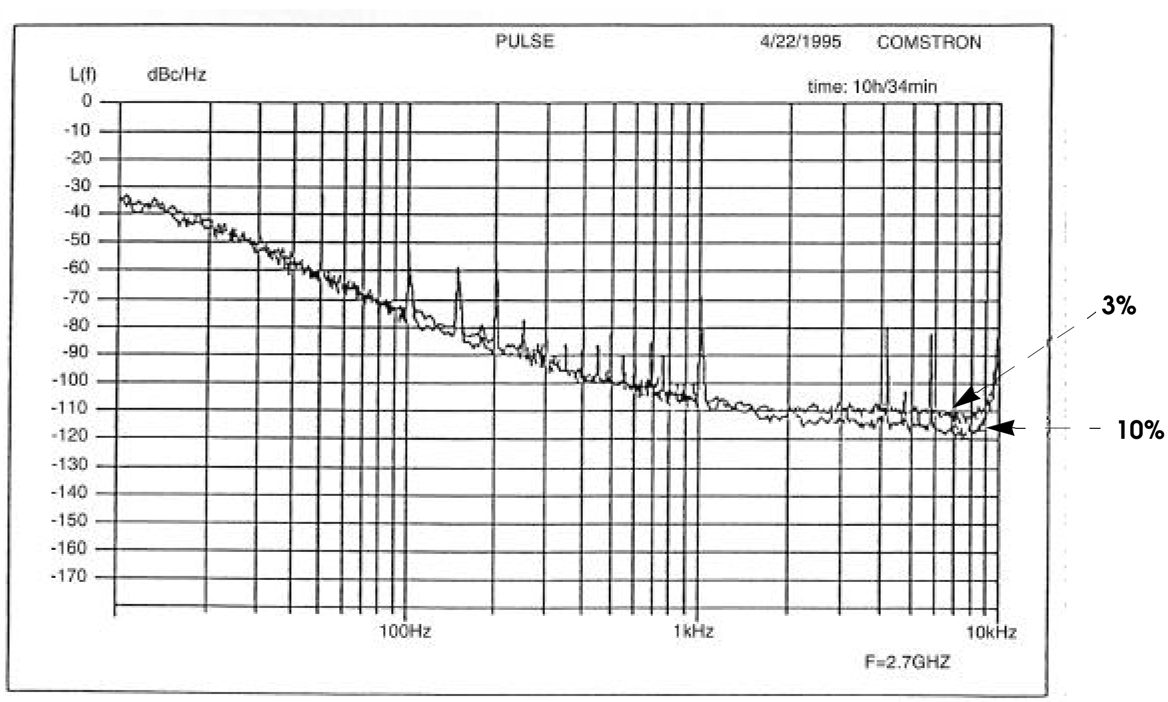
6 PHASE LOCKING

To achieve phase lock it is necessary that the DUT and reference frequencies are close enough to allow the loop acquire lock. The difference between the two frequencies must certainly be less than the selected loop bandwidth. In CW mode the beat frequency between the two is easily measured, but in Pulsed CW mode it is not easily done. It is therefore recommended to make frequency adjustments in CW.

7 RESIDUAL PHASE NOISE

The residual phase noise of the PN9000 increases by the same ratio as the duty cycle. For example, using the standard phase detector the residual phase noise of the PN9000 is -170 dBc/Hz. With a duty cycle of 0.1, the correction factor will be 20 dB and the residual noise floor will increase to -150 dBc/Hz. For most practical measurements this does not pose a problem, however, for some special cases it must be taken into account.

Mathematical spectrum analysis of Pulsed CW signals shows that measurements should be limited to an offset from the carrier of half the PRF. For example, if the PRF is 10 kHz, a measurement out to a maximum offset of 5 kHz is indicated. As a practical matter, as shown on the plot below, measurements are feasible up to an offset almost equal to the PRF. At an offset equal to the PRF and beyond, PRF spurious responses appear at relatively high levels and preclude making measurements.



PRF:	10 kHz	Loop Bandwidth:	180 Hz
Duty Cycle:	3 and 10%	Tune Slope:	500 Hz
PRF Filter:	5 kHz	Gain:	70 dB