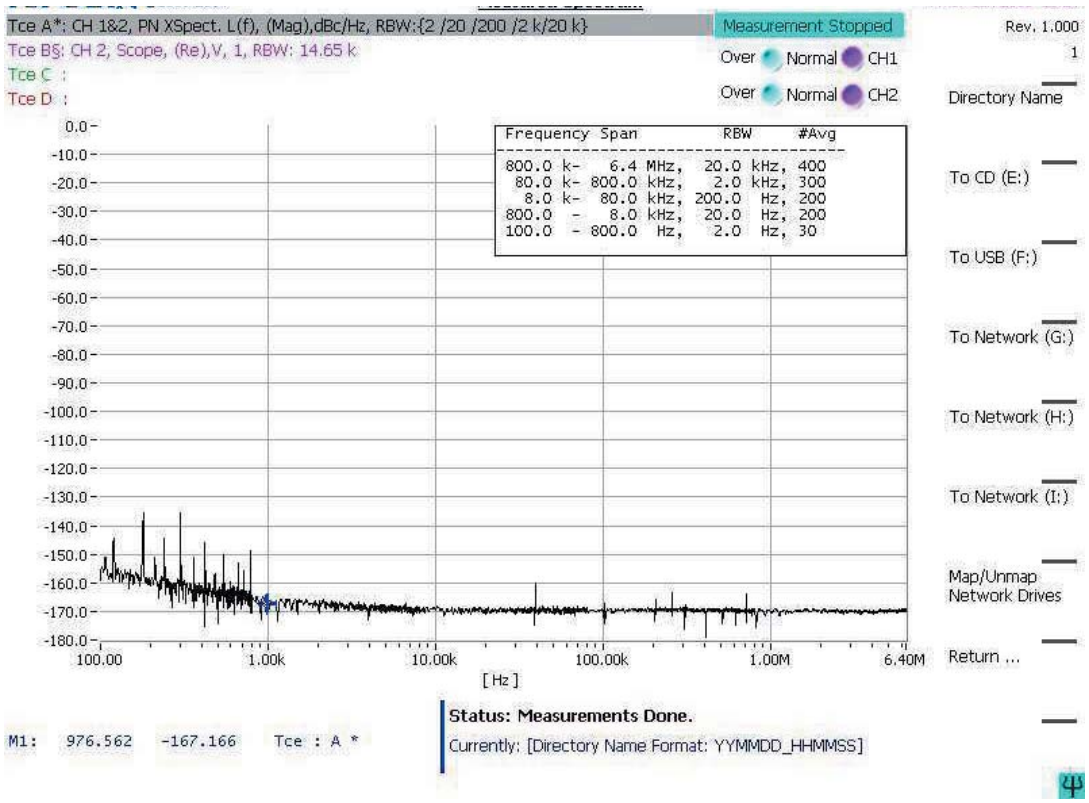
Techniques for Measuring Ultra-Low Phase Noise in Microwave Amplifiers

A Dual Channel Cross-correlation System enables expanded range Phase Noise Measurements

Introduction

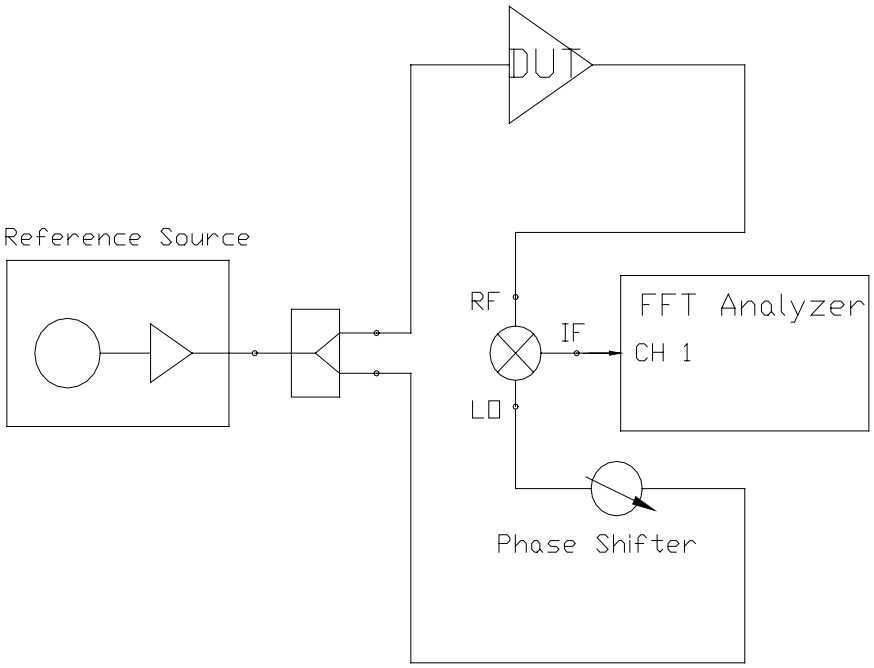
A Dual Channel Cross-correlation PM/AM Noise Measurement System is used to develop low phase noise amplifier solutions covering frequencies from DC to 18 GHz with phase noise performance as low as –180dBc/Hz. The figure below shows the residual phase noise performance of an AML Communications X-Band amplifier operating at 11GHz displaying –167 dBc/Hz at 1 KHz offset from the carrier.



X-Band Low Phase Noise Amplifier
Gain = 16 dB
P1dB = 18dBm
-167 dBc/Hz at 1KHz offset from carrier

Residual Phase Noise Measurement (The Single Channel Method)

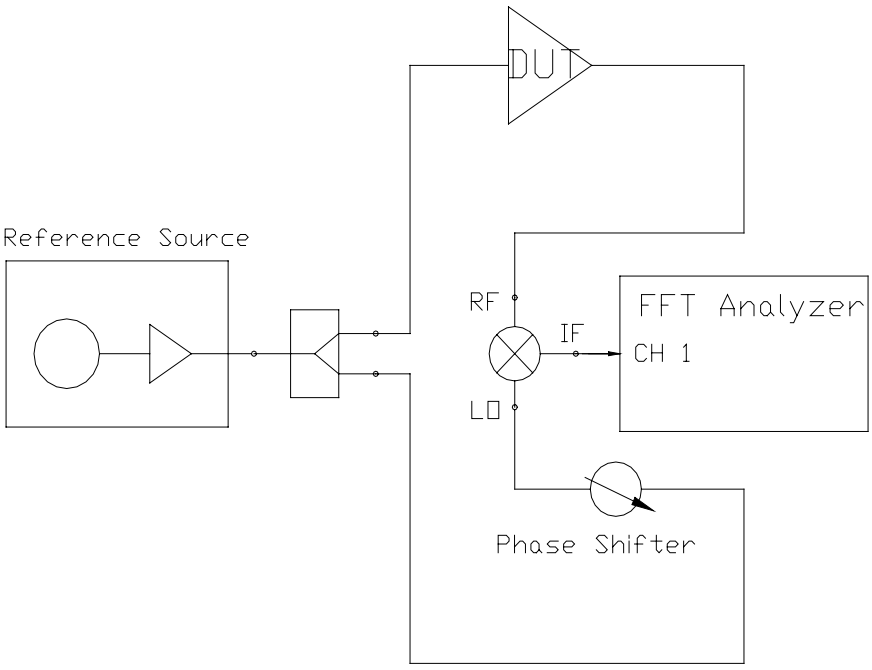
For most residual phase noise measurements, the measurement set up (seen below) consists of a signal source, splitter, phase shifter, and double balanced mixer. The phase shifter is used to bring the RF and LO signals at the mixer into quadrature. The mixer acts as a phase detector and generates a DC voltage at the IF port proportional to the phase difference between the RF and LO. The FFT analyzer processes this signal and the residual phase noise is determined. Single channel measurements lump the phase noise from the DUT, mixer and baseband amplifiers together and calls the result, the residual phase noise of the DUT. There is an inherent inaccuracy in this approach when measuring extremely low phase noise amplifiers.



Block Diagram of Residual Phase Noise Measurement Set Up

Dual Channel Cross Correlation Measurement (The Dual Channel Method)

Cross correlation removes the mixer and baseband LNA noise from the measurement results. Referring to the block diagram of the Dual Channel Cross Correlation Set Up shown below, the FFT analyzer compares the data from two measurement channels for correlation. The phase noise from the device under test is coherent or correlated in both channels and averages to a finite value. The phase noise from the mixers and baseband LNAs are non-coherent (they are independent sources of phase noise) and this noise averages downward toward zero.



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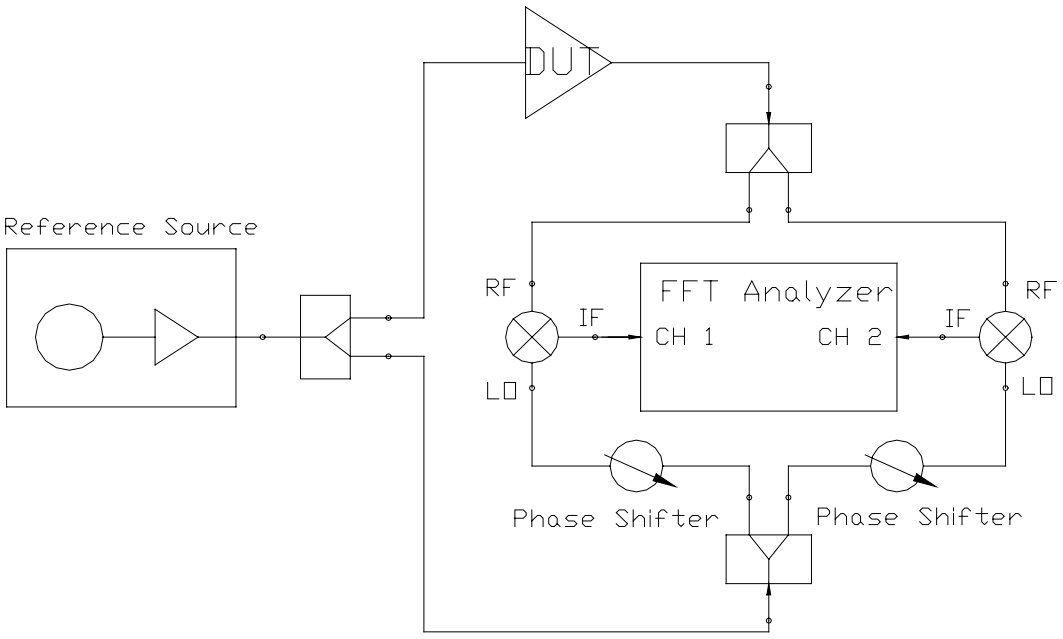
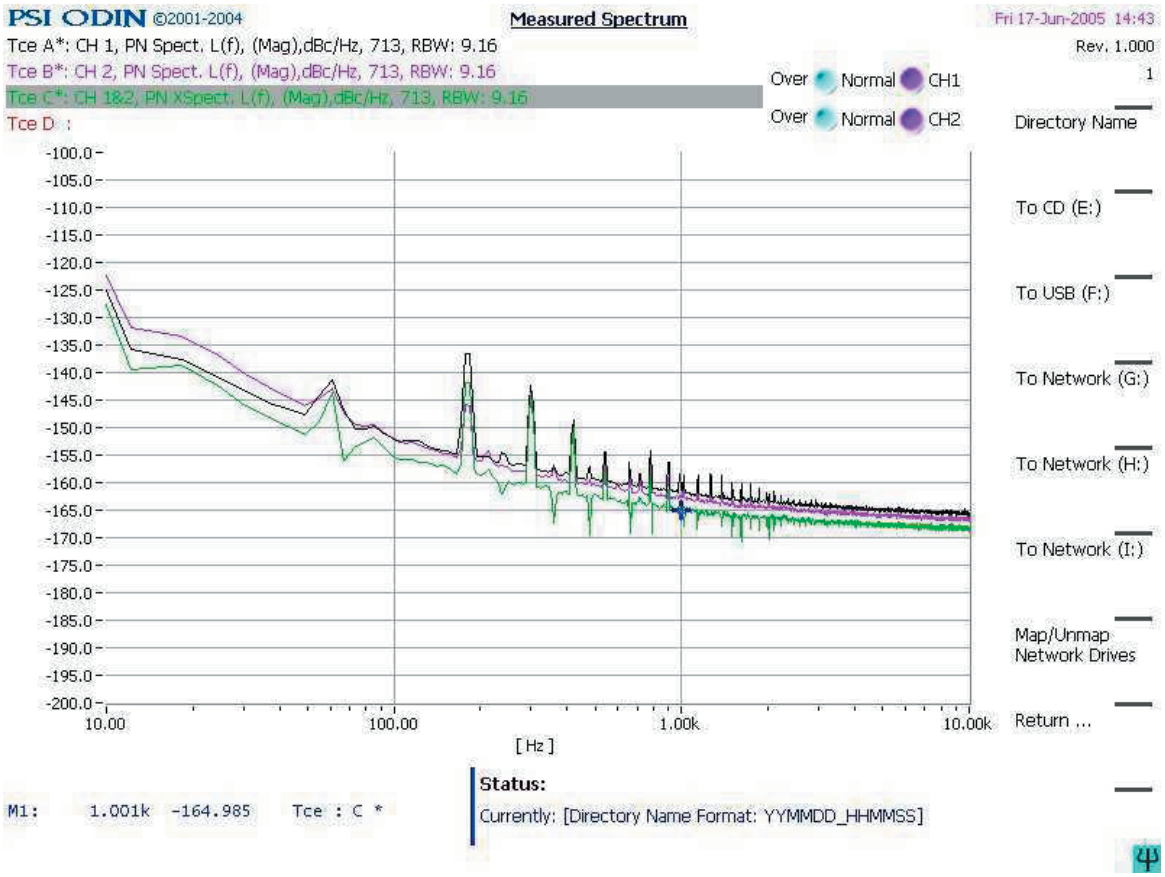


Block Diagram of Dual Channel Cross Correlation Measurement Set Up

The example below illustrates the effectiveness of cross correlation when measuring an amplifier with extremely low phase noise. Traces 1 and 2 (black and red) show the phase noise performance of the amplifier when measured with two separate single channels. Trace 3, with Cross correlation, has removed 4 to 5dB of additive noise from the measurement system. This trace represents the true performance of this amplifier, namely -165 dBc/Hz at 1 KHz offset.



Trace A - Amplifier Performance through Channel 1
Trace B – Amplifier Performance through Channel 2
Trace C – Amplifier Performance with Cross Correlation between channels 1 and 2

Measurement of System Noise floor

With either approach, the noise floor of the measurement system requires consideration. A high noise floor can mask the true performance of a low phase noise device. Ideally, the noise floor is at least 10dB below the noise of the device. The AML noise floor is measured each time a phase noise measurement is made to guarantee the validity of the results. In the example below, Cross correlation has reduced the measurement noise floor by 10 to 15dB.