[Measuring Absolute and Additive Phase Noise of Pulse-Modulated Signals]

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Phase noise is an important parameter for the performance of a radar system. Most radars employ pulse modulation, and the velocity of the target is derived by detecting the Doppler shift of the radar's reflected signal relative to the frequency of the transmitter. The transmitter's own phase noise strongly affects the resolution and accuracy of this measurement, limiting the detection threshold and accuracy of the radar. Therefore, the phase noise of pulsed signals has become an increasingly important measurement.

The contributors to phase noise in pulsed radar systems can be additive or absolute, with different methods used to measure them - each with advantages and disadvantages. Offering a solution for both additive and absolute measurements, the phase-locked loop (PLL) method is well suited to characterizing phase noise performance, as it provides high dynamic range with a low noise floor and is repeatable and reliable. AnaPico's APPH signal source analyzer with a new local oscillator (LO) option is a useful tool for characterizing the phase noise of pulsed signals. This article first discusses its use for absolute phase noise measurements, then addresses additive phase noise measurements of non-oscillating components such as amplifiers.

ABSOLUTE PHASE NOISE

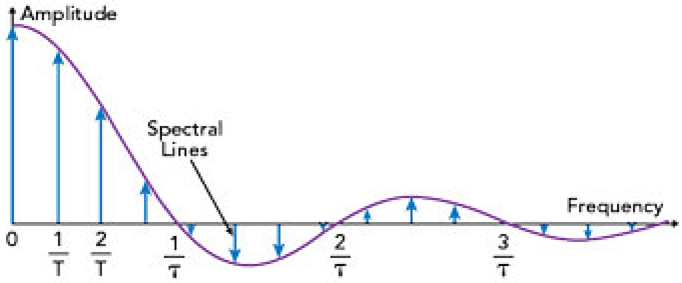


Figure 1 Spectrum of a pulse modulated signal with pulse width τ and pulse period T.

The noise of a pulsed signal consists of the noise coming from the reference and the noise introduced by the pulse modulation. **Figure 1** shows the spectrum of an ideal, pulsed signal with pulse period T and pulse width τ. Above the pulse repetition frequency (PRF), the pulse modulation completely masks the phase noise; therefore, data for the offset frequency above the PRF is usually omitted. Close to the PRF, the phase noise of the signal is increased by the pulse modulation: the summation of the carrier noise with the first spectral image, which is shifted to the right by 1/T. The increase depends on the duty cycle of the pulse modulation, τ/T, and is deterministic.

The PLL measurement method requires a tunable LO to be phase-locked to the signal of the device under test (DUT). Under pulsed conditions, maintaining phase-lock may be tricky. Rejecting instrument noise while the DUT signal is off is also challenging, particularly when measuring very short pulses or very low duty cycles. Low PRF or short pulses may lead to phase drift from phase quadrature, even to a loss of phase-lock if not properly handled. In AnaPico's APPH, sophisticated pulse detection circuitry reliably maintains phase-lock and actively rejects background instrument noise when the pulse is off. As a result, the APPH is capable of reliably measuring pulses at extreme pulse parameters (see **Figure 2**). Since the locking process can only be active during the "on" period and has to wait during the "off" period, low pulse widths, low duty cycles and very high or very low pulse rates may prove difficult to measure. Despite these challenges, the APPH can measure pulses as short as 40 ns and PRFs from 500 Hz to 5 MHz, with duty cycles down to 0.1 percent.

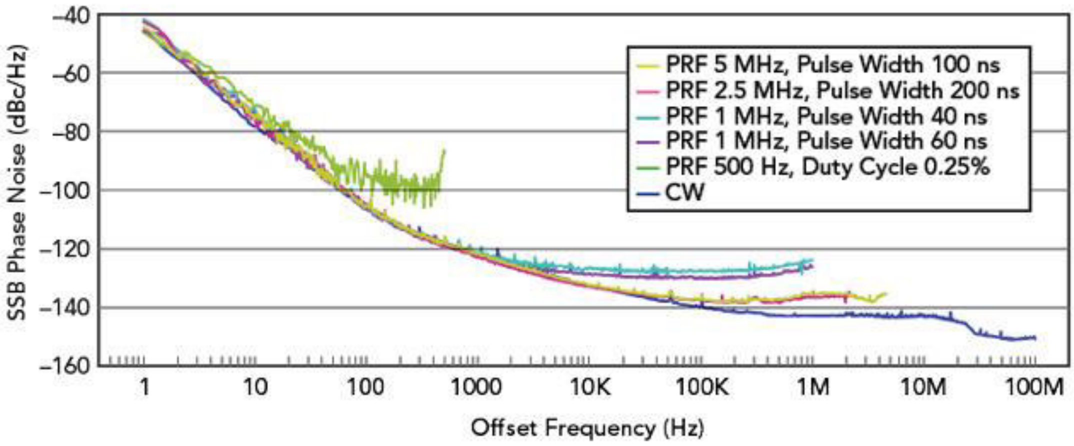
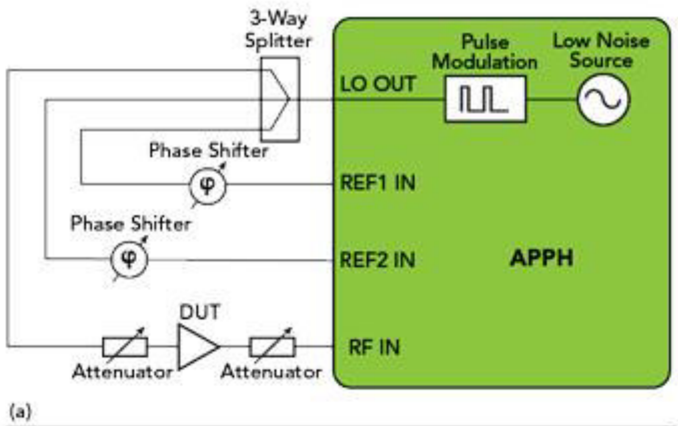


Figure 2 3.8 GHz pulsed signals, with pulse widths ≥40 ns and PRF ≤5 MHz.

ADDITIVE PHASE NOISE



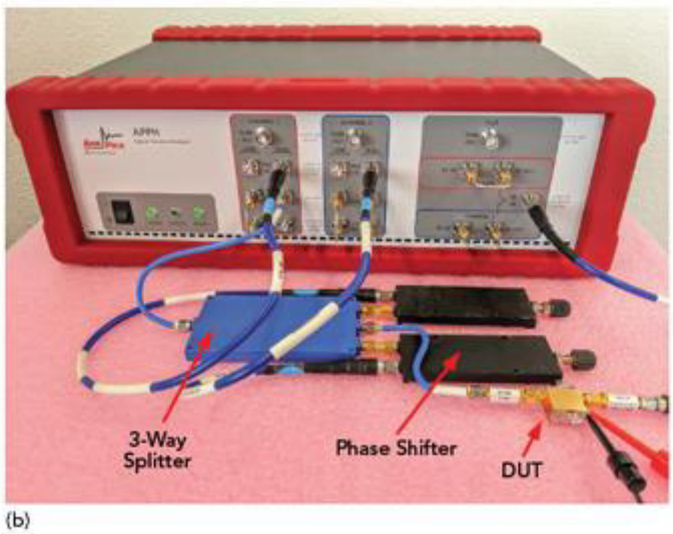


Figure 3 Pulsed additive phase noise measurement using the internal LO of the APPH: block diagram (a) and photo (b) of the setup.

Phase noise in radar systems comes from various sources, not only the frequency synthesizer: most notably, the pulse modulator and power amplifiers. So, when analyzing a pulsed radar system, it is informative to assess the added phase noise from the amplifier stages. To measure additive noise, the amplifier must be operated under real conditions using a low noise, pulse-modulated signal source.

The LO output of the APPH signal source analyzer can be used for this. **Figure 3** shows the setup of a two-channel, cross-correlated additive phase noise measurement of an amplifier. The pulsed driving signal for the DUT is synthesized directly in the APPH and split into three paths and fed into the two REF inputs and the RF input of the signal source analyzer. Besides a three-way splitter, only two mechanical phase shifters are required to tune the reference paths into phase quadrature, where the phase noise of the driving signal is cancelled and the residual noise of the DUT can be measured. The cross-spectrum measurement rejects instrument noise and substantially enhances instrument sensitivity. The APPH software guides the user through two calibration steps, making the measurement virtually as simple as an absolute phase noise measurement.

SUMMARY

AnaPico's APPH signal source analyzers enable easy and reliable measurements of the absolute and additive phase noise of pulsed signals up to 65 GHz. Using an advanced PLL method, the analyzer provides great dynamic range and, combined with cross-correlation analysis, low noise floor. The instrument offers intuitively usable standard (option PULSE) or enhanced (option NPS) pulse measurements. The newly released LO front-end option provides access to the internal low noise, pulsed signal sources, eliminating the need for external sources to measure additive phase noise and making the measurement setup faster and more intuitive.

AnaPico Ltd.
www.anapico.com