

Application Note AN2005

Measuring Phase Noise of Pulsed RF Signals using the APPH Signal Source Analyzer

Application

In pulsed radar systems, the phase noise of the receiver local oscillator sets the minimum signal level that must be returned from a target in order to be detectable. Since the overall dynamic range of the radar system is influenced by the noise of the transmitted signal, it is not only important to know the absolute noise of the individual oscillators but to know the residual or additive noise of the signal processing devices like power amplifiers and pulse modulators. Because the final signal in most radar systems is pulsed, making absolute phase noise measurements on the pulsed carrier is essential to determining the overall performance of the system.

This application note discusses the various trade-offs in a phase noise measurement of a pulsed RF signal and how easy it can be performed using the APPH signal source analyzer.

Introduction

Pulsed noise measurements have traditionally been made using customized test sets with complex and lengthy calibration procedures. The APPH signal source analyzer has the capability to make phase noise measurements on pulsed carriers and devices in a fast and repeatable way. This allows to save time in the development process and final characterization.

A pulsed RF signal is usually described by its **pulse period T** and its **pulse width τ** . The **pulse repetition frequency PRF** is the frequency at which the pulses are repeated. The relation between PRF and T is

$$\text{PRF} = 1 / T$$

More sophisticated pulsed RF signals may consist of time-varying pulse width τ or arbitrary (periodic) pulse patterns.

The duty cycle refers to the ratio τ/T of the (average) pulse width to the pulse period. More generally, it represents the fraction of the time where the pulse is on during the time of observation.

A pulse-modulated signal in the frequency domain is no longer a discrete spectral line but spreads out over frequencies both above and below the nominal signal frequency in the form of modulation sidebands due to random phase fluctuations. This is the “phase noise” of the signal. At any given offset from the carrier the phase noise can be represented as a pair of discrete sidebands.

Now the question arises how pulse modulation affects the distribution of the SSB phase noise of a CW carrier.

When the CW carrier is amplitude modulated by the pulsed waveform, the sine wave represented by each spectral line in the pulsed waveform spectrum produces two sidebands, an upper sideband and a lower sideband. The modulation process “aliases” the noise of the CW carrier onto each of the sideband lines in the pulsed carrier spectrum.

The composite noise at the carrier line (center frequency) has been increased by the sum of the aliased noise on each of the sideband lines weighted by the sampling function $\text{sinc}(x) = \sin(x)/x$ function. Phase noise information on the CW carrier at offsets above $\text{PRF}/2$ has been aliased to within $\pm\text{PRF}/2$ from the carrier in the resultant pulsed carrier spectrum.

The effect of this, from a phase noise measurement perspective, is that after detection there is no new phase noise information above offsets of $\text{PRF}/2$.

It should be observed that the shape of the CW carrier’s phase noise energy distribution curve will affect the degree to which the noise is degraded at different offsets from the carrier. Typically, the slope of the close-in phase noise (0 to 100 Hz) is very steep, on the order of 20 to 40 dB per decade. Due to the $\sin(x)/x$ weighting, aliased noise at these offsets will be well below the CW noise and little degradation will be seen. At higher offsets, up to $\text{PRF}/2$, the degradation will be more apparent, especially if the CW noise curve has a pedestal.

Performing the Measurement on an APPH signal source analyzer

With the APPH, phase noise of pulsed signals can be analyzed straightforward with pulse repetition frequencies up to several MHz, with narrow pulses below 100 ns, or even with time varying pulse width.

Measuring noise on pulsed carrier will be complicated by the following effects:

- Reduced dynamic range due to reduced signal power (duty cycle)
- Limited frequency offset range (PRF/2)
- Saturation of IF stages due to PRF feed through

The specialized architecture of the APPH can mostly overcome the limiting factors and allows performing even very demanding measurement tasks.

When connecting with an APPH that supports option PULSED, the GUI will give you the option to activate its capabilities, allowing measurements of pulsed RF signals as shown in Figure 1.

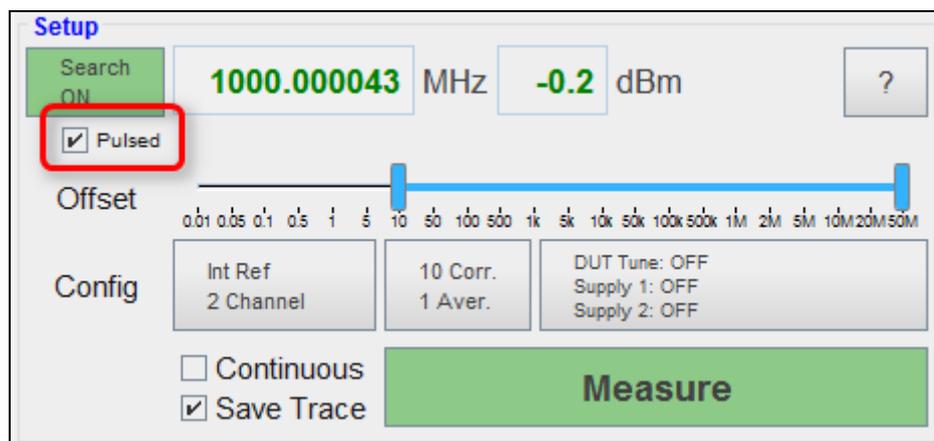


Figure 1 The Pulsed Option can be activated with the check box

Next, the system needs to know the carrier frequency in order to select the correct internal paths. The automatic detection of the carrier frequency and power level may not always work especially for narrow modulation pulses. In order to tell the GUI the signal parameters, there are two options:

- 1) If possible, switching off the pulse modulation on the RF carrier (i.e. configuring CW only) will allow the unit to detect the signal. When activating the pulse modulation again, the last properly detected frequency will be memorized by the APPH.

2) If switching off the pulse modulation is not possible, the carrier frequency must be set manually by deactivating the signal search. Click on the green *Search ON* button to turn it off. The button will turn red. Now the exact frequency can be entered into the text field.

The measurement can be started by pressing the green *Measure* button.

Upon start, the unit will automatically detect pulse repetition rate (PRF) and duty cycle (i.e. pulse width) and perform the locking process and final measurement autonomously. Depending on the signal and pulse configuration the locking process might take a few seconds.

The resulting phase noise will be displayed up to the detected pulse rate to help interpret the measurement. As highlighted in the section before, according to sampling theory, the valid measurement offset range is limited to PRF/2 (because a pulsed RF signal is essentially a sampled version of the CW carrier with sampling rate equal to the PRF).

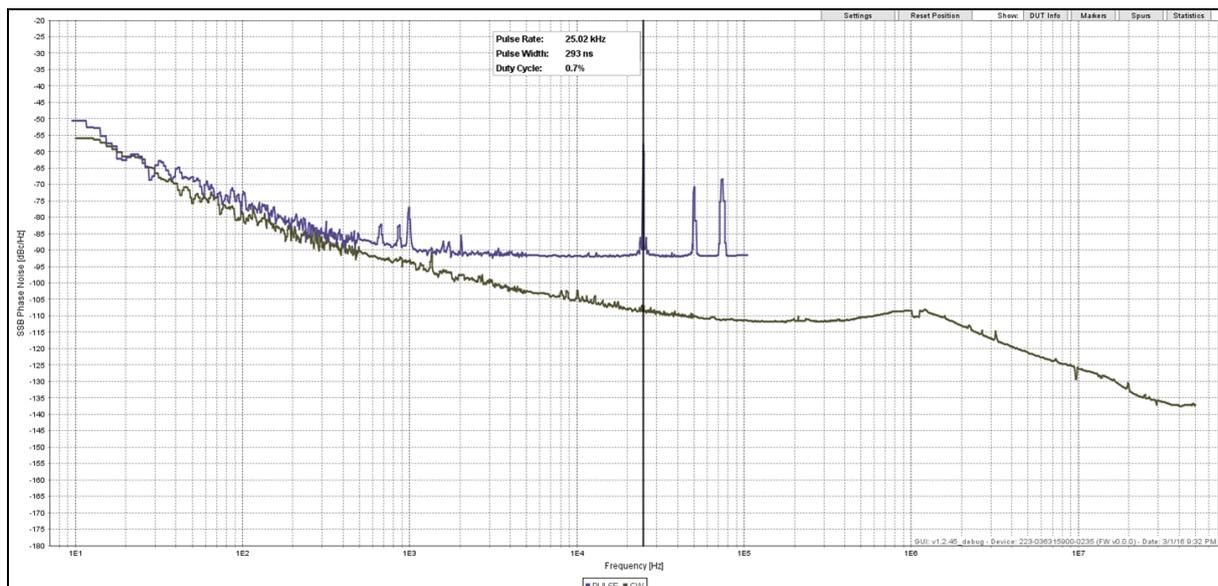


Figure 2 Example measurement of a 10 GHz signal in both CW and pulsed mode.

The resulting phase noise plot for an example measurement can be seen in Figure 2. It shows the absolute phase noise of a 10 GHz signal.

The measurement was performed for both, CW (in green) and the pulsed carrier (in blue). The pulse modulation was configured with a pulse rate of 25 kHz and a pulse width of 0.3 μ s, resulting in a duty cycle of 0.7%. As expected from our previous analysis, for small offsets up to a few hundred Hz, the phase noise of the pulse carrier does not deviate from the CW carrier phase noise. At higher frequency offsets however, the resulting phase noise of the pulsed signal is substantially degraded.

Conclusion

The demand for phase noise measurement solutions that can handle pulsed RF signals increases. This application note has explained the basic terminology of pulsed phase noise measurements and has shown how simple complex pulsed measurements can be performed. The steps are shown to perform an absolute phase noise measurement of a pulsed RF signal with the APPH signal source analyzer.