Phase Noise: Difference Between Time Domain & Frequency Domain

Difference in the Time Domain

Phase Noise

In the time domain, phase noise manifests as jitter. The term *jitter* aptly describes random and unpredictable fluctuations in an RF signal's zero-crossing points from their ideal, periodic timing. In other words, the signal sometimes arrives earlier or later than it ideally should, introducing timing uncertainty that degrades signal stability and performance.

Noise Figure

The noise figure of an amplifier represents the total noise it contributes to the output. Simply put, it is the random increase in output power, voltage, or current fluctuations over time. If an amplifier's output were a perfect sine wave, this added noise would appear as small, erratic deviations or fuzziness on the waveform, reflecting random, broadband noise superimposed on the ideal signal.

Difference in the Time Domain

Phase Noise

In the frequency domain, phase noise appears as noise sidebands surrounding the carrier tone. Rather than a single narrow spectral line at the carrier frequency, real oscillators exhibit sidebands that spread outward due to random phase variations. The shape and distribution of these sidebands depend on the internal noise sources and characteristics of the oscillator.

Noise Figure

Viewed in the frequency domain, the noise figure is represented by the overall noise floor of the amplifier. An ideal amplifier would amplify only the existing thermal noise (such as that generated by electron motion in semiconductor junctions). However, an amplifier with a high noise figure increases the output noise power across a wide frequency range, effectively raising the system's noise floor and degrading sensitivity.

Connection Between the Time and Frequency Domains for Phase Noise

While phase noise and noise figure are distinct parameters, they share a close relationship. An amplifier's noise figure contributes to the overall noise floor of an RF system, and under certain conditions, this noise can interact with the desired signal to produce phase noise components.

This effect becomes especially apparent when amplifiers operate near saturation. For instance, a local oscillator (LO) with a high noise figure can introduce additional noise that mixes with strong nearby signals, a phenomenon known as reciprocal mixing. In a receiver chain, when a mixer translates signals from the LO to the intermediate frequency (IF), the LO's phase noise manifests as sidebands that extend into adjacent frequency channels. This effectively raises the receiver's noise floor and degrades overall system performance.