Oscillator Purity Fundamentals

2

1 Introduction

A sinusoidal oscillation is described completely by its amplitude and frequency. The purity of the oscillation pertains typically to only the frequency or period of oscillation. This is because an oscillator is typically used to synchronize events in time. This applies to wireless transceivers as well as digital circuits. The amplitude of oscillation, once above a threshold value, is typically irrelevant as long as it can generate an action (event) on the subsequent circuit block. An oscillation that is perfectly pure has a constant period of repetition. In frequency domain, the perfect repetition translates into a single tone, for a sinusoidal oscillation anyway.

Historically, observing periodicity in time predates the observation of spectral purity for obvious reasons. Ancient Egyptians noted that Sirius rises to its place besides the sun exactly every 365 days. They divided the year into twelve 30-day months and a short 5 day month that was called the “little month”. Their calendar is still used today by peasants in the countryside of Egypt, side-by-side with the Gregorian calendar, as it fits perfectly the Egyptian climate and the flooding of the Nile. Their calendar was the basis of the modern calendar we use today. The Babylonians of today’s Iraq used a lunar calendar that follows the periodicity of the moon, a cycle of 29 to 30 days. They are the ones who divided the day into smaller units that relate to their base-60 numeral system. Around the 16th century, in the era of great expeditions, there was a great need for accurate clocks for navigation. Determining longitude accurately was not possible without a tool that can tell time with great accuracy [1]. Galileo sketched out the concept of the first pendulum-based clock. It was Harrison who first implemented a clock that can tell time within one second of error per day [1]. Various designs of mechanical movements were implemented over the centuries that followed and are perfected today in Swiss mechanical watches. The 1920s witnessed the first quartz clock that enabled much higher frequency/period stability. Later, this fueled the clock industry in Japan. For more accurate time bases, the atomic clock is used as a calibration source. The search for the most accurate clock is in essence the search for a high long-term stability signal source. The question of noise in signal sources was not of concern until World War II. Only then was the study of noise in the oscillator's phase was born. In essence, phase noise relates to the short-term stability of the oscillator's period, frequency, or phase.

Signal purity measures can be divided into two main categories: deterministic and stochastic. Deterministic *impurity* comes from spurious signals that show in the signal spectrum as delta-Dirac impulses, known as *spurs* at a fixed frequency offset from the main tone. Stochastic *impurity* arises from stochastic variation of signal phase and are manifested in noise skirts around the fundamental frequency. Another way of quantifying stochastic purity is by looking at the signal in time domain where stochastic perturbations are manifested as perturbations in the zero crossings of the sinusoidal waveform. For practical RF receiver design purposes, amplitude perturbations are typically of little concern because mixers are not sensitive to them. In transmitters, however, the situation is somewhat different. Amplitude noise would interfere with neighboring channels just as phase or frequency noise does if it spills out of its allotted bandwidth.

In this chapter we briefly describe the basic concepts of signal purity both in time and frequency domains. The reader who is familiar with these concepts can skip this chapter and advance to chapter 3.

2 Timing Jitter

A pure oscillation repeats in time precisely every T seconds, where T is called the oscillation *period*. In other words, if we set a particular threshold voltage level, the oscillation waveform will cross this threshold in a given direction precisely every T seconds. In the presence of noise, the points in time where