Section 2. Understanding the Sampled Output of a DDS Device

An understanding of sampling theory is necessary when analyzing the sampled output of a DDS-based signal synthesis solution. The spectrum of a sampled output is illustrated in Figure 2-1. In this example, the sampling clock (f_{CLOCK}) is 300 MHz and the fundamental output frequency ($f_{OUT)}$ is 80 MHz.

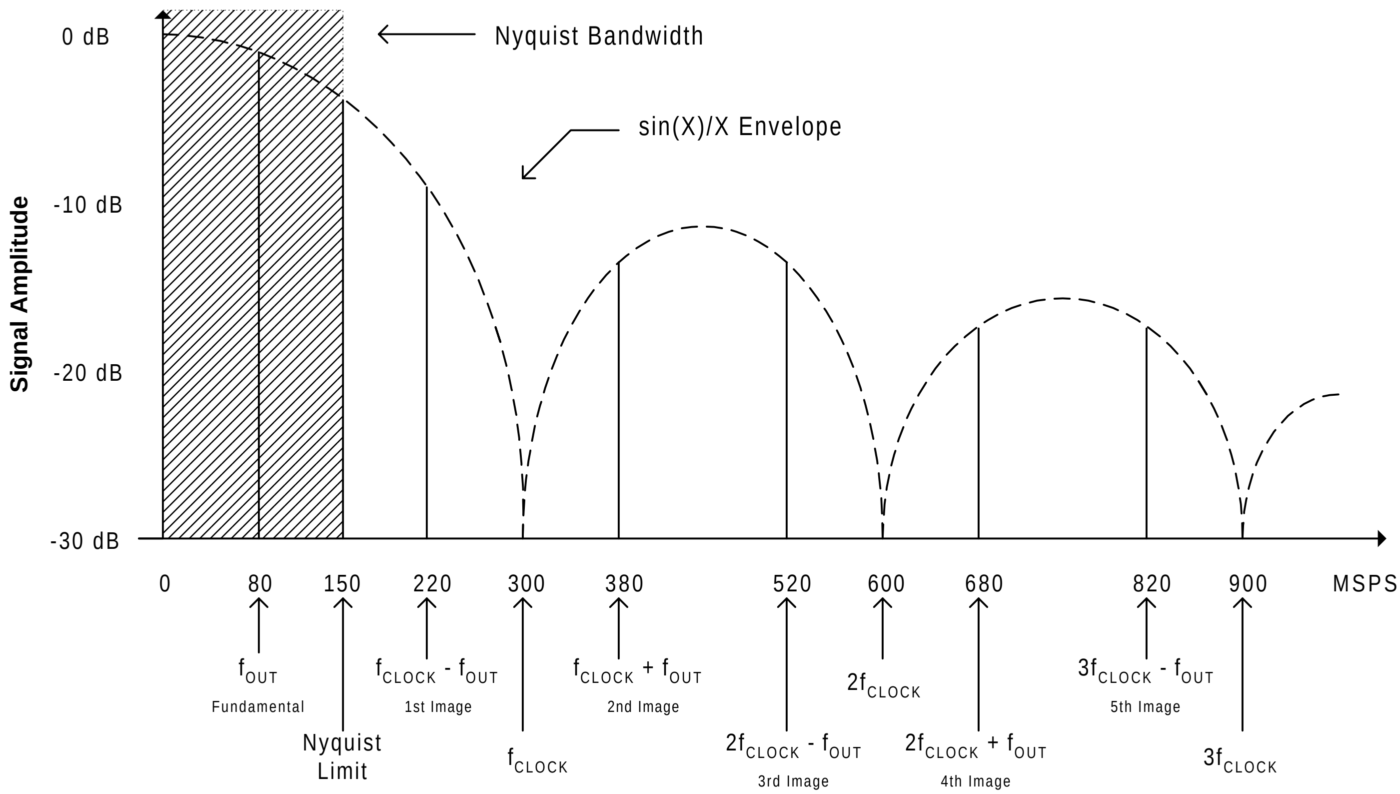

Figure 2-1. Spectral Analysis of Sampled Output

The Nyquist Theorum dictates that there is a minimum of two samples per cycle required to reconstruct the desired output waveform. Images responses are created in the sampled output spectrum at $f_{CLOCK} \pm f_{OUT}$. The 1st image response occurs in this example at $f_{CLOCK} – f_{OUT}$ or 220 MHz . The 3rd, 4th, and 5th images appear at 380 MHz, 520 MHz, 680 MHz, and 820 MHz (respectively). Notice that nulls appear at multiples of the sampling frequency.

In the case of the f_{OUT} frequency exceeding the f_{CLOCK} frequency, the 1st image response will appear within the Nyquist bandwidth (DC - ½ f_{CLOCK}) as an aliased image. The aliased image cannot be filtered from the output with the traditional Nyquist anti-aliasing filter.

In typical DDS applications, a lowpass filter is utilized to suppress the effects of the image responses in the output spectrum. In order to keep the cutoff requirements on the lowpass filter reasonable, it is an accepted rule to limit the f_{OUT} bandwidth to approximately 40% of the f_{CLOCK} frequency. This facilitates using an economical lowpass filter implementation on the output. In section X of this seminar, there will be discussion on creating and isolating image responses as a mechanism for synthesizing higher agile frequencies from DDS devices.

As can be seen in Figure 2-1, the amplitude of the F_{OUT} and the image responses follows a sin(X)/X rolloff response. This is due to the quantized nature of the sampled output. The amplitude of the fundamental and any given image response can be calculated using the sin(X)/X formula. Per the rolloff response function, the amplitude of the fundamental output will decrease inversely to increases in its tuned frequency. The amplitude rolloff due to sin(X)/X in a DDS system is –3.92 dB over its DC to Nyquist bandwidth. As was previously shown in Figure 1-4, DDS architectures can include an inverse SINC filtering which pre-compensates for the sin(X)/X rolloff and maintains a flat output amplitude (± .1 dB) from the D/A converter over a bandwidth of up to 45% of the clock rate or 80% of Nyquist.

It is important to note in the sin(X)/X response curve shown in Figure 2-1 that the amplitude of the 1st image is substantial: it is within 3dB of the amplitude of the fundamental at $f_{OUT} = .33\ f_{CLOCK}$. It is important to generate a frequency plan in DDS applications and analyze the spectral considerations of the image response and the sin(X)/X amplitude response at the desired f_{OUT} and f_{CLOCK} frequencies.

The other anomalies in the output spectrum, such as integral and differential linearity errors of the D/A converter, glitch energy associated with the D/A converter, and clock feed-through noise, will not follow the sin(X)/X roll-off response. These anomalies will appear as harmonics and spurious energy in the output spectrum and will generally be much lower in amplitude than the image responses. The general noise floor of a DDS device is determined by the cumulative combination of substrate noise, thermal noise effects, ground coupling, and a variety of other sources of low-level signal corruption. The noise floor, spur performance, and jitter performance of a DDS device is greatly influenced by circuit board layout, the quality of its power supplies, and the quality of the input reference clock. Each of these subjects will be addressed individually in following sections of this tutorial.