

Section 10. Using DDS Images as Primary Output Signals in VHF/UHF Applications

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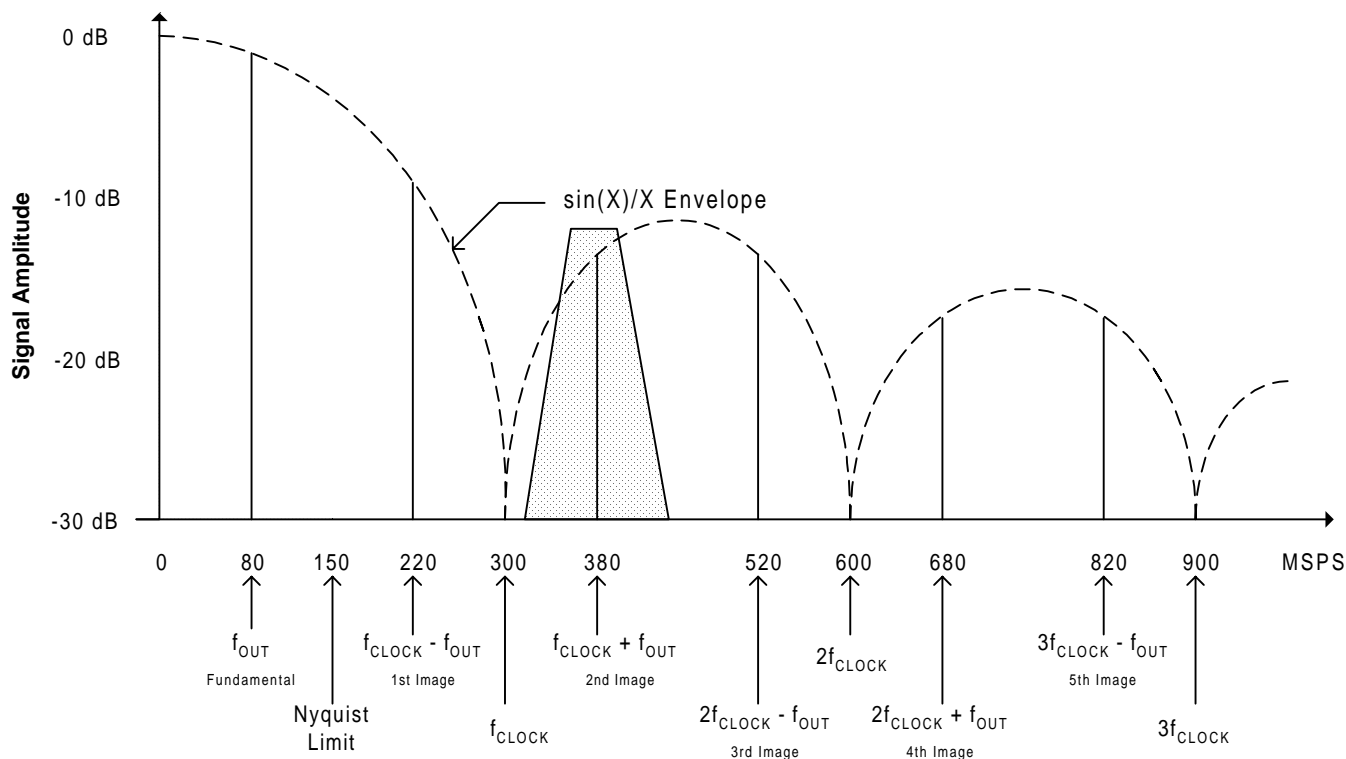


Figure 10-1. Frequency Representation of the DDS/DAC Output Spectrum

Some Properties of the DDS/DAC Output Signal

The DDS/DAC sampled output has many important properties that can be exploited. First, it is a “real” signal, that is, it is composed of both positive and negative frequencies. These signals are symmetrical or “mirrored” about 0 Hz. Secondly, the sampled output implies that the positive and negative frequencies are replicated at locations separated by the sample frequency, both above and below 0 Hz to infinity (theoretically). These replications of the fundamental signal are called images

Using the example in Figure 10-1, one can conclude that if $f_{out} = 80$ MHz then there must also be a negative frequency component at -80 MHz. Furthermore, since the sample frequency is 300 MHz, these *two* signals should be replicated at integer multiples of the sample frequency, both above and below 0 Hz. Figure 10-1 shows only the positive frequencies, but one can see that if a -80 MHz component existed, it should be replicated at 220 MHz ($-80 + 300 = 220$), 520 MHz ($220 + 300 = 520$), 820 MHz ($520 + 300 = 820$), etc. The same is true for the fundamental signal located at $+80$ MHz which will have replica’s of itself located at 380, 680, 980 MHz, etc. The same thing is going on below 0Hz as well. Theoretically, the amplitude of the images of a

sampled signal are the same as the fundamental and that the images continue to infinity. In reality, the DAC output amplitude follows the relationship established by $\sin(x)/x$ seen in Figure 10-1 above.

So what's different about the *negative frequency image* at 220 MHz and the *positive frequency image* at 380 MHz in Figure 10-1? A change in frequency of the fundamental output will cause the positive image to track the change whereas the negative image will change frequency in the opposite direction! A positive phase shift of the fundamental will result in a corresponding phase shift of the positive image and a negative phase shift for the negative image. These attributes have been termed "*spectral inversion*" and are traced back to the mirror image property of a "real" signal. If images are to be used as primary output signals, then the effects of spectral inversion should be accounted for.

Phase Noise

Phase noise of images will degrade since phase noise is referenced to the "carrier" power (dBc). It stands to reason that a reduction in carrier level (as experienced in utilizing images) while maintaining the same noise power in the signal "skirt" will result in a degraded phase noise measurement.

Image SFDR & SNR

The disadvantage of using images as primary output signals is basically the decrease in signal to noise ratio and SFDR (spurious-free dynamic range). The image amplitude as well as the fundamental amplitude are all subject to $\sin(x)/x$ amplitude variations with frequency. The value of x is the ratio of the frequency of interest to the sample frequency multiplied by π . When calculating sine, use radians instead of degrees. Unfortunately, spurious signals in the DDS/DAC output spectrum seem to get more numerous and larger the further one goes from the Nyquist limit! (see Figure 10-2A). Even given this constraint, it is possible to locate "sweet" spots in the sea-of-noise where the images reside, Figure 10-2B.

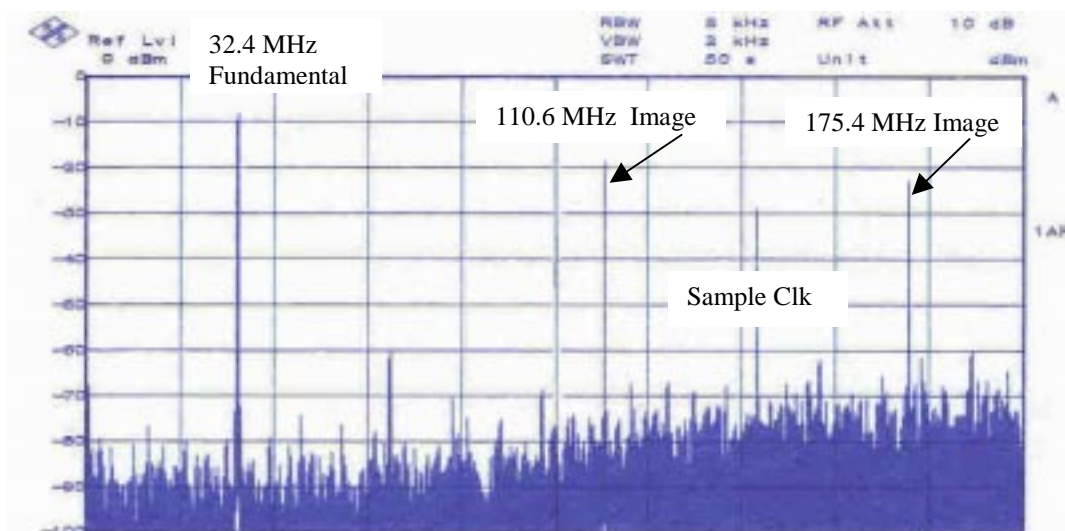
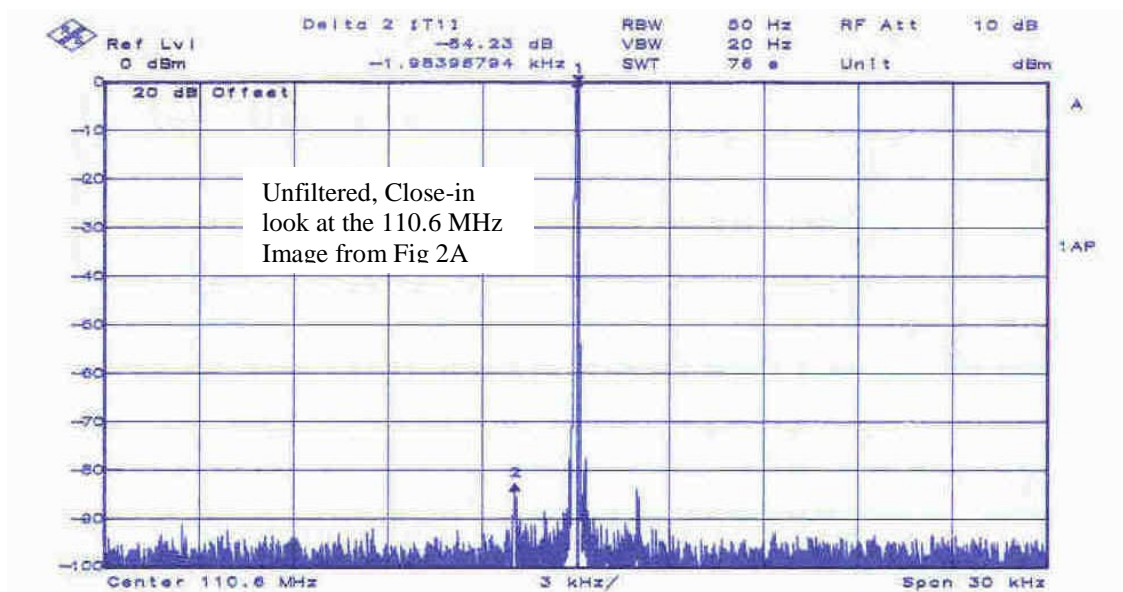


Figure 10-2A & B: A (above) Images in a dc to 200 MHz View and B (below), -84 dBc SFDR at 110.6 MHz



If the spectrum of the image in Figure 10-2B is intriguing then one can certainly see why DDS/DAC images should be considered as primary output signals. Perhaps the most challenging aspect of this technique is the need for adequate bandpass filtering of the image to separate the image from the surrounding spurs. SAW filters have been successfully implemented with DDS images at VHF and UHF frequencies; however, their inherent loss may require the use of an RF amplifier, such as inexpensive MMIC's. Figure 10-1 graphically shows the intent of bandpass filtering as well as identifying the power levels of various images calculated using $\sin(x)/x$.

Figure 10-2A shows that the frequency region above Nyquist is heavily populated with spurious signals in addition to the images of the fundamental signal. This suggests that if SFDR is

important to a particular application, then the movement of the image frequency will be restricted due to the likely presence of nearby spurs. Applications such as frequency hopping will require special attention to avoid transmitting spurious signals along with the desired signal when operating in super-Nyquist areas.

Summary

Use of super-Nyquist DDS/DAC output frequencies can save several costly RF stages (oscillator, mixer, filter) by directly producing the desired output frequency through use of naturally occurring images. Images are not harmonics of the fundamental, they are linearly transposed replicas of the fundamental signal. The remarkable advantage of image utilization is that a low fundamental and sample clock frequency produce useable signals well above the accepted range that Nyquist's theory predicts. This technique is not suitable for some applications; however, many VHF applications, including clock-generators, can be well served using this simple technique. Use of images is restricted to the first three or four images since amplitude loss of succeeding images reduces SNR to unusable levels