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The Effects of Timing Jitter on A/D Conversion

One of the least understood aspects of A/D conversion is the impact that jitter on the sampling clock has on the accuracy of the conversion process. In this whitepaper we will show that the timing jitter has a serious impact on quality of the the conversion process, as well as discuss the effects of the *spectrum* of the jitter on A/D conversion.

Any engineer that has analyzed A/D converters has probably seen the formula for signal to quantization distortion (in dB) due to timing jitter

$$SQNR = -20 \log_{10} 2\pi f_{max} t_{jitter} \tag{1}$$

where f_{max} is the highest frequency present in the input signal and t_{jitter} is the standard deviation of the timing jitter. Equation 1 has important implications for almost all conversion systems. However, Equation 1 is actually only valid for a single sinusoid with frequency f_{max}, and is a very good approximation for any narrowband signal with approximate maximum frequency f_{max}.

It is fairly simple to derive more general formula for the $SQNR$ induced by timing jitter, but the result is strongly dependent on the signal structure. For example an OFDM signal will have jitter-induced $SQNR$ of

$$SQNR = -20 \log_{10} 2\pi f_{max} t_{jitter} + 4.66dB \tag{2}$$

where f_{max} is the highest subcarrier frequency. Note that the 4.66 dB “gain” over the single sinusoid result is nearly a full bit of effective resolution, so that using the basic formula leaves almost a bit “on the table”. Many single-carrier systems have a somewhat larger $SQNR$ improvement over the base result.

The average $SQNR$ results in Equations 1 and 2 are average signal-to-noise ratio over the entire signal band; in other words it is total signal power divided by total noise power. When performing link analyses we often treat the resulting noise as if it were white Gaussian noise, and find an associated bit-error-rate degradation. A very important, and occasionally critical factor is that the *spectrum* of the timing-jitter-induced quantization noise is dependent on the *spectrum* of the timing jitter, and is rarely white. Treating the quantization noise as white frequently provides good approximations but in some cases, especially in OFDM systems, the error can be substantial and always for the worse. High performance coding such as turbo codes exacerbate the problem substantially.

Accurately simulating timing jitter errors is very challenging and requires considerable expertise. Analytical formulas and the understanding that comes with experience are critical in determining the impact of jitter on DSP systems.

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