Estimating the signal band noise in sigma delta modulators

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1.0 Introduction:

The output of a one bit sigma delta modulator is a very high frequency (relative to the Nyquist frequency) bit stream. The reason is, that in a sigma delta modulator high sampling rates are used to get high accuracy in A/D or D/A or related circuits.

The point is, that an input signal is sampled at such high rates that a very small part of the transient input signal becomes an average of the multiple samples taken at high frequencies.

The action of the delta-sigma modultor creates, what is known as the NTF or the noise transfer function (and also the STF , the signal transfer function). This brief paper deals with the NTF. The NTF is a high pass function of noise. The noise in the signal band of the modulator is suppressed and the out of band noise is allowed a high pass response. The out of band noise is subsequently removed by the decimation filter.

We wish to examine the estimation of the signal band noise using a relatively siple expression for higher order modulators.

2.0 The problem:

Figure 1 shows the frequency domain components of the modulator output. (Only the major components of the composite signal are shown).

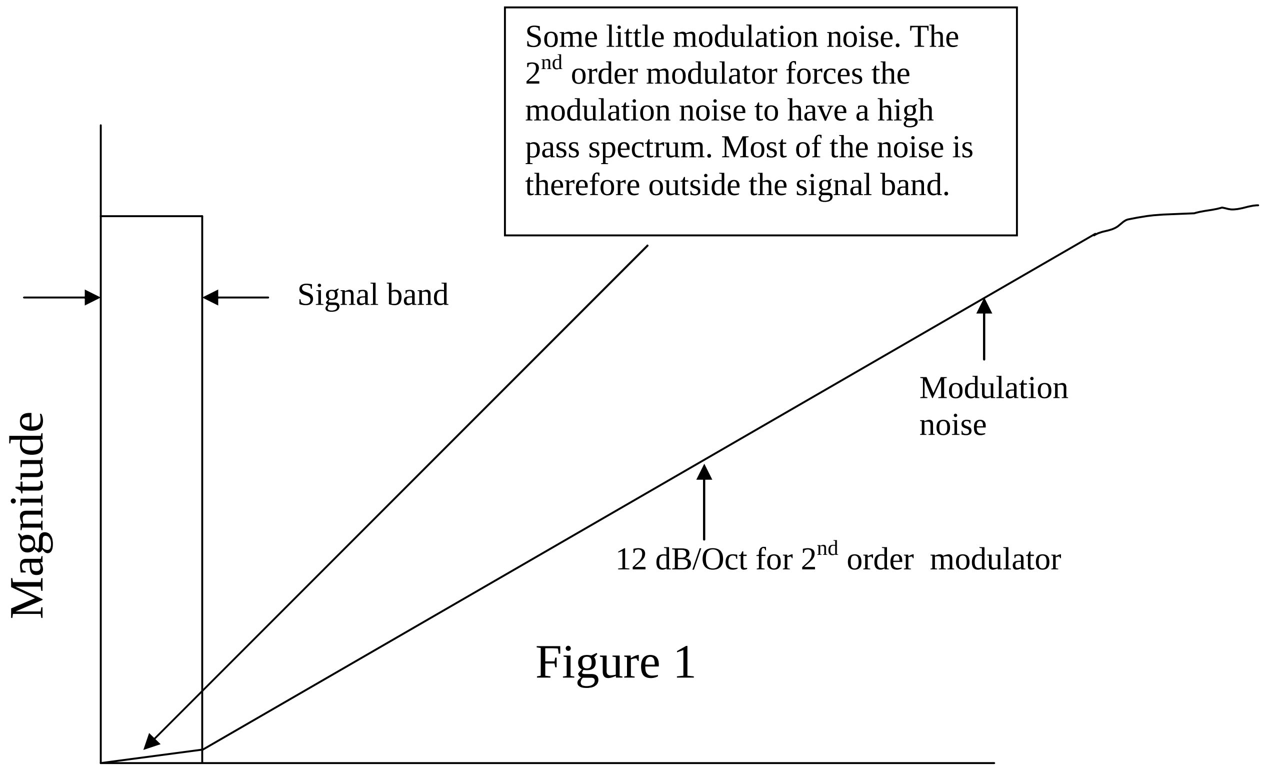

Figure 1

The modulation noise needs to be filtered, the out of band signal components need to be filtered, the circuit noise and interference needs to be filtered. (These last few components are not represented in the figure above.) In order to filter the modulation noise, a relatively simple low pass filter could be used, since the modulation noise rises slowly (in the frequency domain). However, abrupt low pass filters are needed to filter the signal out of band components and these can become very difficult to design and build at high frequencies.

3.0 The signal band noise estimation:

A simple expression for the signal band rms noise is:

$$N0 = 0.577[\pi^{L}/\sqrt{(2L+1.0)}](2.0/OSR)^{L+1/2} \qquad 1.0$$

This expression is true for a 2 level quantizer. (1 or 0.)

In the above expression,

L = the order of the modulator (number of loops in thre modulator)

OSR = Oversampling ratio (sampling frequency / Nyquist frequency)
In general the second order modulator is the most popular (but third order modulators are finding their way into systems. The problem with third order modulators is of course the stability of the modulator). Therefore we will focus on the noise of second order modulators given by:

$N0 = 0.577 * 2812.38 * (2/OSR)^{2.5}$
$N0 = 1622.74 * (2/OSR)^{2.5}$

From the above generic equation.

N0 is calculated with respect to OSR to give the results shown below. Note the decrease in noise with increasing OSR.

OSR versus rms noise in dB for a second order modulator

Table 1.0

OSR	Rms noise	Rms noise (dB)
1	5.656854249	15.0515
2	1	0
4	0.176776695	-15.0515
8	0.03125	-30.103
16	0.005524272	-45.1545
32	0.000976563	-60.206
64	0.000172633	-75.2575
128	3.05176E-05	-90.309
256	5.3948E-06	-105.36
512	9.53674E-07	-120.412