Evaluating the Level of Discrete Components in Stable32 PSD Plots

Introduction

The Stable32 power function and its various power spectral density plots are intended primarily for the analysis of noise. If a discrete component is present in a plot, it must be evaluated in terms of power spectrum (PS) rather than a power spectral density (PSD). That requires multiplying the PSD value by the applicable effective noise bandwidth (ENBW, in Hz), which is determined by the properties of the window function being used and the size of a Fourier frequency bin. The EFBW (in bins) is a property of the windowing function, and the FFT frequency resolution (f_{res} in Hz per bin) depends on the sampling rate, data length, and averaging factor used in the analysis. The former, shown in the table below, is also tabulated in the Stable32 Help file for the Power function, while the latter is displayed as the Fourier Interval (Hz) in the Power function dialog box.

ENBW, bins				
Window Type	# Windowings			
	0	1	2	3
Hanning	1.000	1.500	1.944	2.310
Hamming	1.000	1.363	1.817	2.184

The numerical level of a discrete component is determined from the PSD value as:

Amplitude of discrete component = PSD value · f_{res} · ENBW.

In the most common case of a £(f) PSD plot, the correction (in dB) is given by:

Correction for discrete component = 10 log (f_{res} · ENBW),

which, for the case of a sub-Hz f_{res} and a ENBW near unity, is a negative value that is added to the PSD value in dBc/Hz to yield the desired PS value in dBc.

Example

As an example of evaluating a discrete spectral component, consider the following 2^{20} point set of simulated phase noise with a 1 kHz sampling rate and a combination of white FM noise at a level $\sigma_y(1)$ = 1e-11 plus a sinusoidal component at a level of 1e-9 and a period of 1e-1 seconds (10 Hz), with a carrier frequency of 10 MHz.

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Power-Law Noise Generation:
Points:
Num=1048576
Tau=1.00000e-03

Fractional Freq Parameters:
Offset=0.00000e+00
Drift/Tau=0.00000e+00
Sine=1.00000e-09
Period=1.00000e-01

Noise Parameters:
RW FM=0.00000e+00
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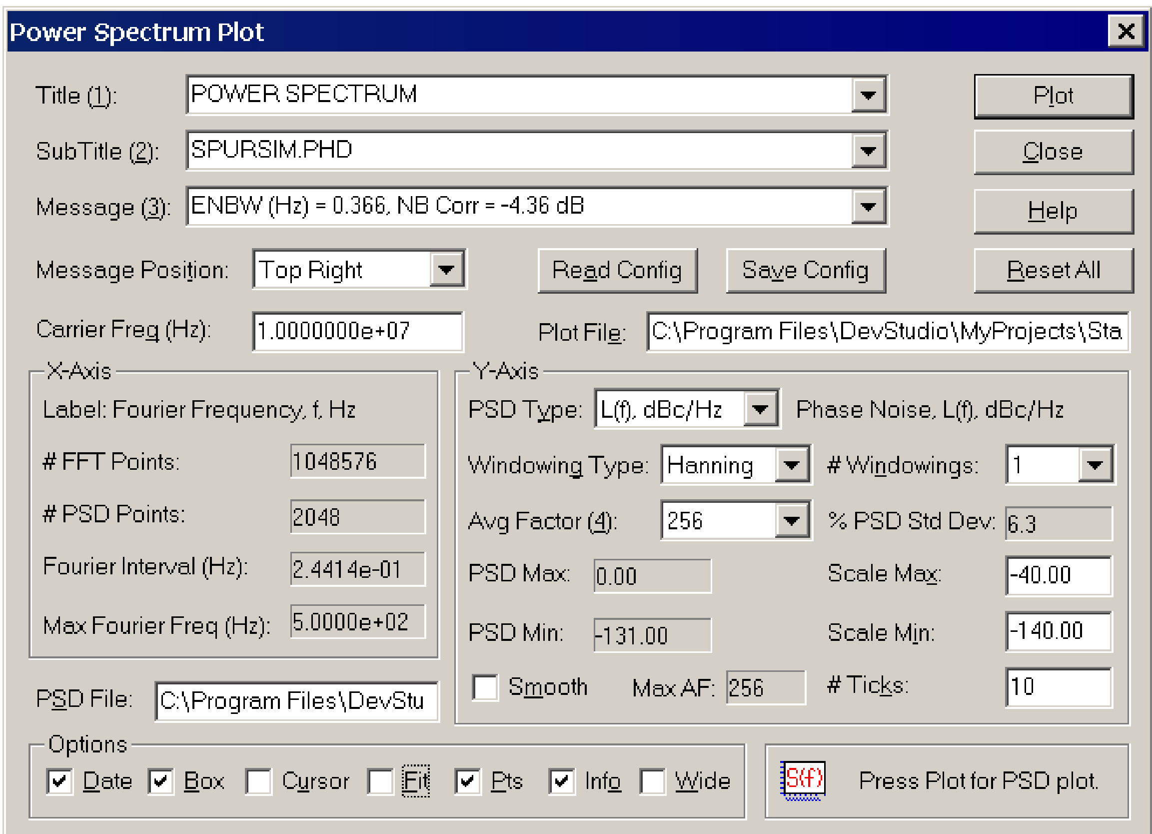
F FM=0.00000e+00
W FM=1.00000e-11
F PM=0.00000e+00
W PM=0.00000e+00
```

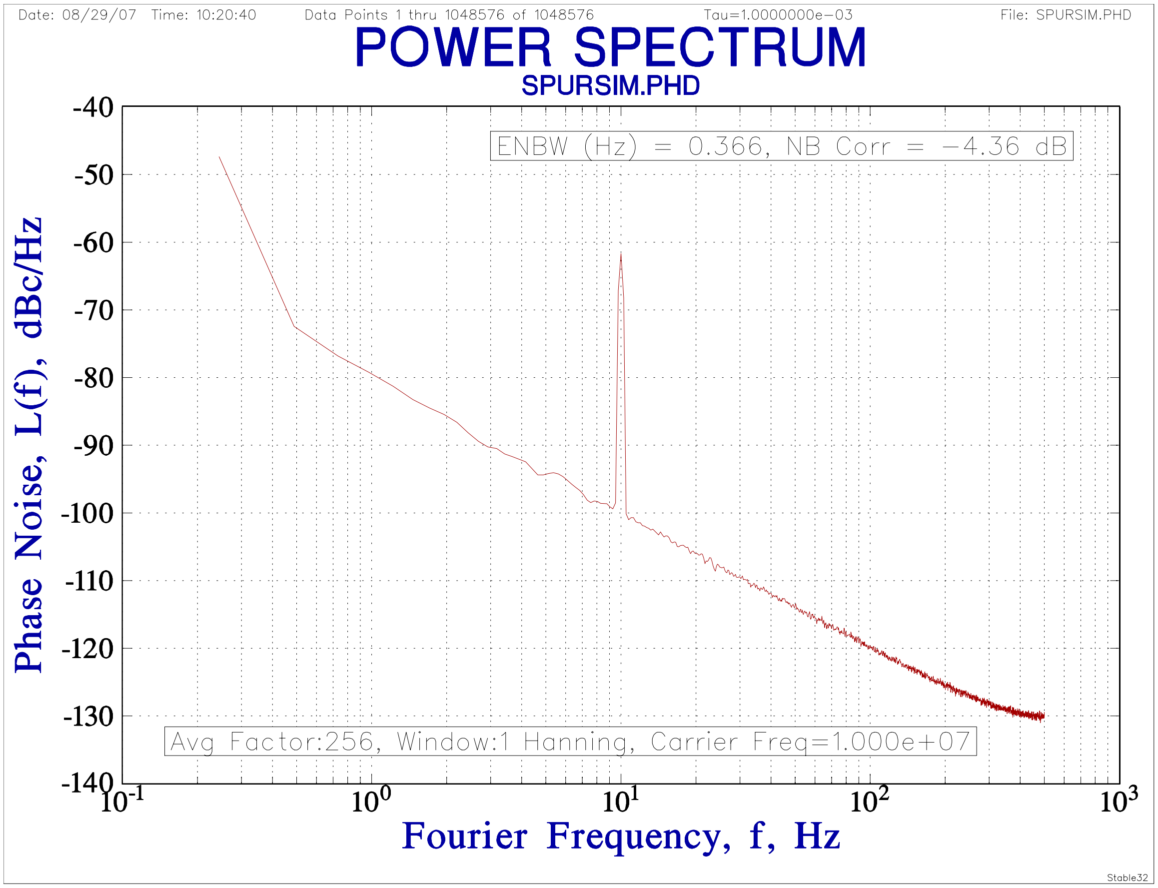
The expected level of the discrete component can be calculated as follows:

$\pounds(f)$, dBc = $20\cdot\log_{10}[\Delta f/(2\cdot f_{mod})] = 20\cdot\log_{10}[(1e\text{-}9)\cdot(1e7)/(2)\cdot(10)] = -66$ dBc

The Stable32 Power function setting used for the analysis of these data set are shown below:



The resulting $\pounds(f)$ PSD plot is shown below with one Hanning window and an averaging factor of 256. Note the ENBW and narrowband log correction factors shown in the message display.



The 10 Hz spectral component appears at a level of -62 dBc/Hz, but that value must be corrected for because it is a discrete component. The ENBW value in Hz is the product of the Fourier interval (2.441e-1 Hz/bin) times the ENBW value of 1 Hanning window (1.500 bin) which equals 0.3662 Hz, and has a log narrowband (NB) correction value of $10 \cdot \log_{10}(0.3662) = -4.36$ dB. Adding this correction, which is available as a plot message, to the PSD value of the 10 Hz component PSD level gives a corrected PS value of -66 dBc, in agreement with the expected value of the simulation.

In this case, the PSD and PS values are fairly close together, but that is not necessarily true, depending on the size of the data set and the averaging factor used. The PSD value of the discrete component is 3 dB lower for each doubling of the averaging factor. The ENBW value is available as a message on the plot, and, if the averaging factor is able to be adjusted so that it is close to 1 Hz, the PS spur level in dBc will be calibrated to be nearly the same as the PSD noise in dBc/Hz. A large discrete component will distort a fit to the underlying noise, and should not be used to quantify the noise level.

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