



Hideo Okawara's Mixed Signal Lecture Series

DSP-Based Testing – Fundamentals 11 Windowing

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Preface to the Series

ADC and DAC are the most typical mixed signal devices. In mixed signal testing, analog stimulus signal is generated by an arbitrary waveform generator (AWG) which employs a D/A converter inside, and analog signal is measured by a digitizer or a sampler which employs an A/D converter inside. The stimulus signal is created with mathematical method, and the measured signal is processed with mathematical method, extracting various parameters. It is based on digital signal processing (DSP) so that our test methodologies are often called DSP-based testing.

Test/application engineers in the mixed signal field should have thorough knowledge about DSP-based testing. FFT (Fast Fourier Transform) is the most powerful tool here. This corner will deliver a series of fundamental knowledge of DSP-based testing, especially FFT and its related topics. It will help test/application engineers comprehend what the DSP-based testing is and assorted techniques.

Editor's Note

For other articles in this series, please visit the Verigy web site at www.verigy.com/go/gosemi.

Windowing

The coherent condition was discussed in the seventh article of this series. It is the most important test condition in DSP-based testing. You must set up your test condition to make it strictly coherent. However, if for some reason you have a situation that you cannot make strictly coherent, there is a workaround technique. It is called "windowing," which is the theme of this issue.

Coherent Condition

For reviewing the discussion, let's see what the coherent condition is. It is described as the equation as follows.

Ft: Test Signal Frequency
Fs: Sampling Frequency
M: Number of Test Signal Cycles (an Integer Number)
N: Number of Sampling Points (an Integer Number)

$$\frac{Ft}{Fs} = \frac{M}{N} \quad (1)$$

M and N are mutually prime. Usually N is settled 2^n for FFT operation so that M is an odd number. Then a whole number of cycles of the test signal can be captured in the unit test period that is N/Fs .

Fractional Number of M

If M in Equation (1) cannot be settled as an integer number for some reason, the end point of the captured waveform cannot smoothly be connected to the start point of the data. It means the waveform does not look continuous. In Figure 1, the green line shows that the whole 23 cycles of the sinusoidal waveform is exactly captured in the unit test period of 512 points. This is coherent and nice condition. In the case of the yellow line, 23.3 cycles of the sinusoidal waveform is captured so that there is a big discrepancy between the end and the start points.

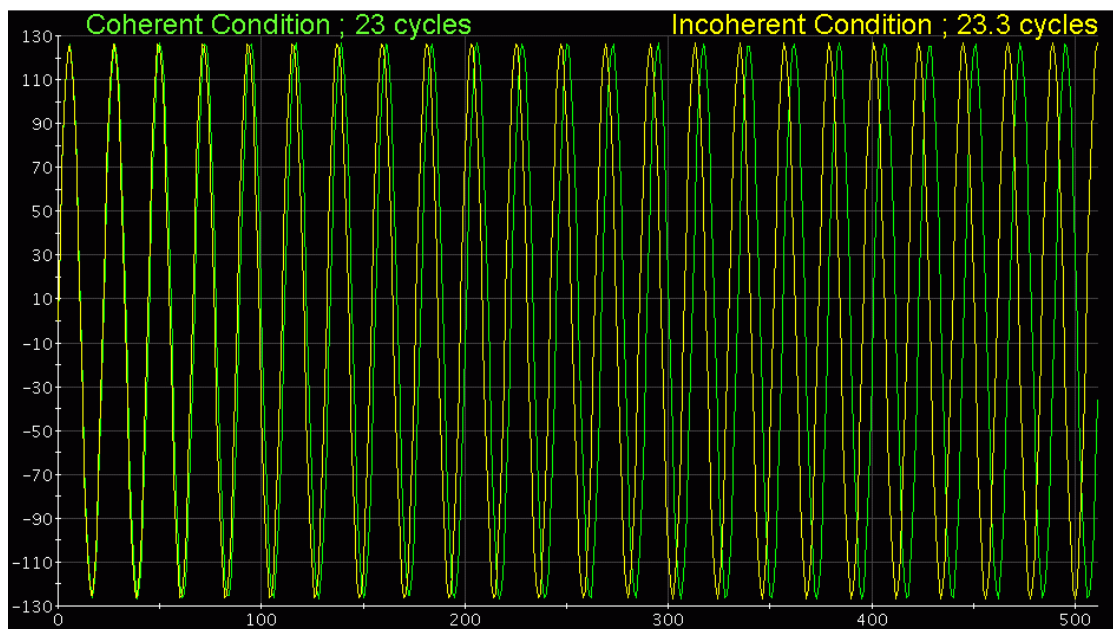


Figure 1: Fractional-M Waveform (yellow)

Performing FFT to the waveforms in Figure 1, the frequency spectrum looks as Figure 2. In Fourier transforms, the waveform captured in the UTP is supposed to be infinitely continuous and repetitive. When the whole number of cycles is captured in the UTP, the frequency spectrum looks nice and clear as the blue lines in Figure 2, which is the FFT result of the green waveform (23 cycles) in Figure 1. The spectrum of the yellow waveform (23.3 cycles) in Figure 1 looks the red line in Figure 2, which is significantly smeared, and you cannot see the small components

such as harmonics or spurs buried in the fake noise floor. This is the problem when M becomes a fractional number.

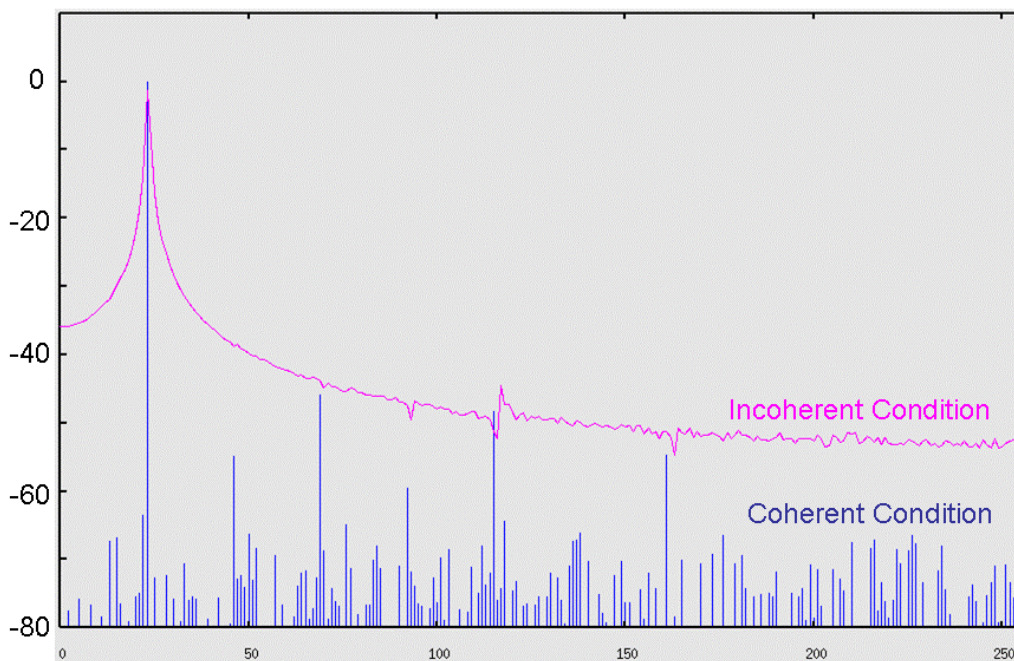


Figure 2: Smearing Spectrum for Fractional Number M

Window Parameter

If you cannot settle M as an integer number for some reason, windowing can improve the smeared spectrum in FFT. The most typical FFT API in the Verigy 93000 is coded as follows.

```
DSP_SPECTRUM(WaveArray, SpectrumArray, DB, 1.0, RECT, 0);
```

The fifth parameter indicates the window. RECT is applied when M is an integer, which is a normal condition. Actually RECT means no windowing. When you make a test plan, you should make your test condition as perfect coherent situation as possible and apply "RECT" in an FFT API.

There are three windows parameters available in the Verigy 93000; HANNING, HAMMING and FLAT_TOP. Each window has the shape as Figure 3 shows.

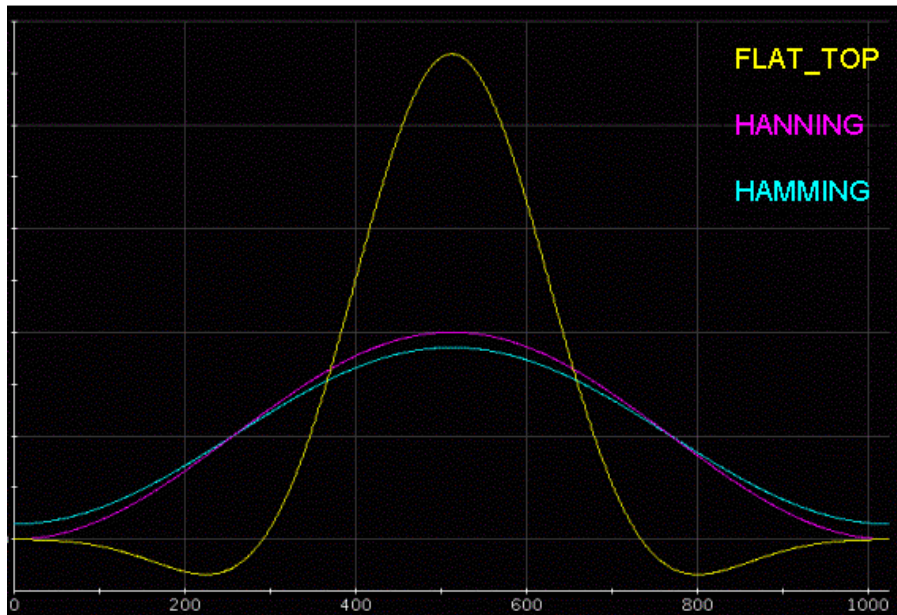


Figure 3: Three Window Shapes

A window function is a weighting parameter to the input data. Since the windows become zero or very small at both ends, when the weighting shape is multiplied to a target waveform, it makes the discontinuity between the end and the start points ineffective.

HANNING and FLAT_TOP are very useful windows for our regular jobs. Author has never had an opportunity to employ HAMMING in the data processing.

HANNING

Hanning window is expressed by the equation as follows.

$$h(i) = \frac{1}{2} \left(1 - \cos \left(\frac{2\pi \cdot i}{N} \right) \right) \quad (2)$$

where $i=0,1,2,\dots,(N-1)$ and N is the number of data.

When Hanning window is applied to the fractional-M waveform in Figure 1, it makes the envelope of the waveform as spindle shape as Figure 4.

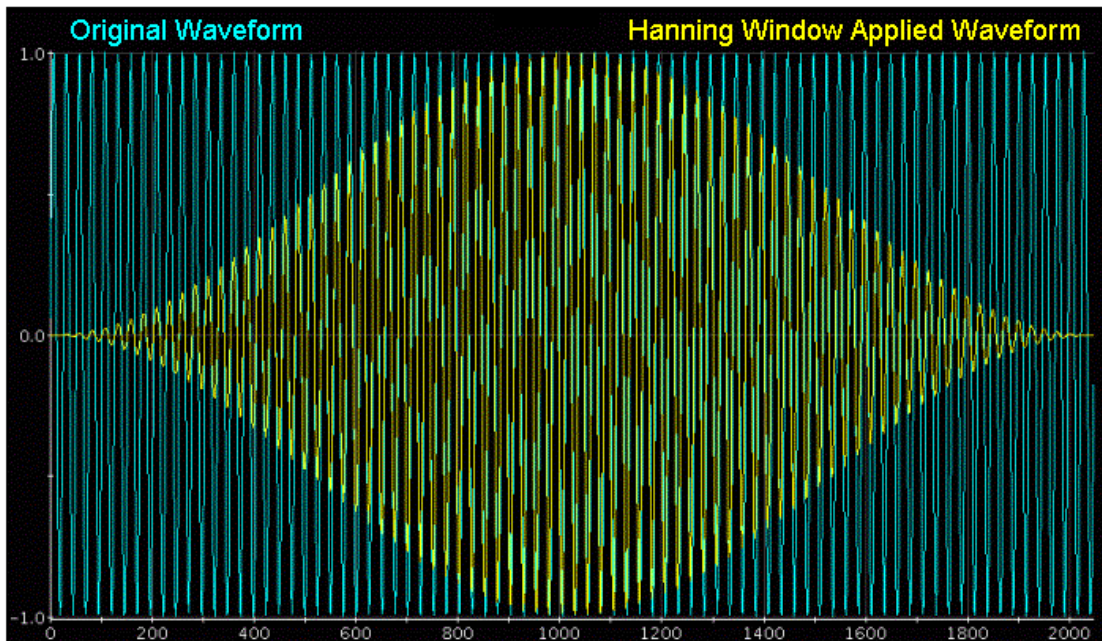


Figure 4: HANNING Window Applied Waveform

FFT with HANNING is coded as follows, and the spectrum appears as Figure 5.

```
DSP_SPECTRUM(WaveArray, SpectrumArray, DB, 1.0, HANNING, 0);
```

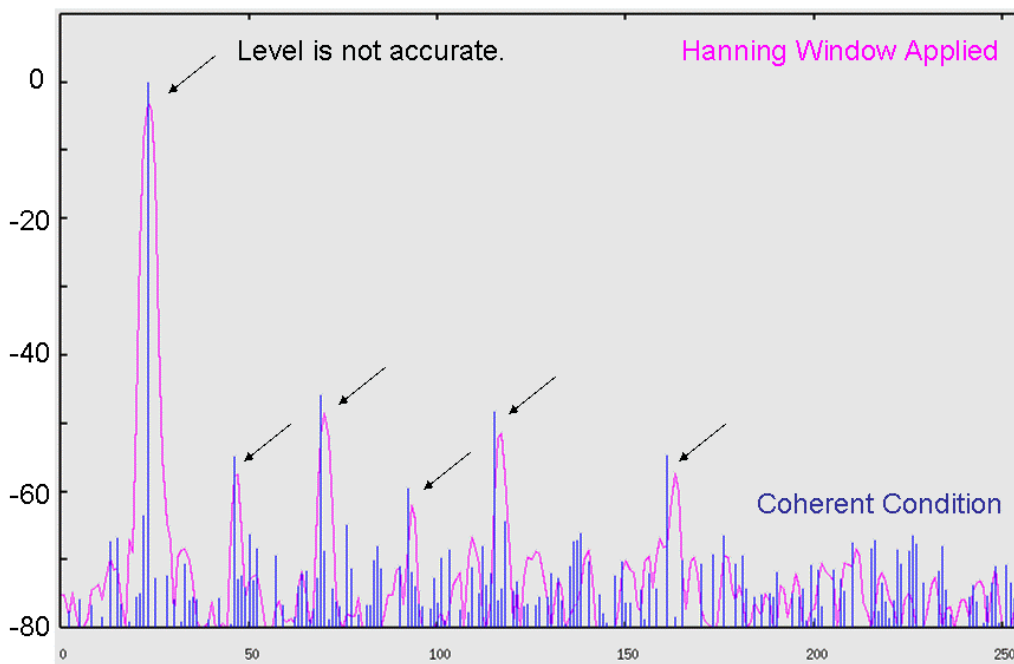


Figure 5 HANNING Window Applied Spectrum (Red Line)

As you can see, the spectrum is improved as sharp without significant smearing so that you can clearly see harmonics and spurs. However, since the window already distorts the original waveform, the power of the waveform is affected so that the levels are not accurate. On the other hand, Hanning window has elegant equation so that it can be very effective in the spectrum estimation in the fractional-M situation. This topic will be discussed precisely in the next newsletter article.

FLAT_TOP

This window is very useful for our regular jobs. When you apply FLAT_TOP in the FFT, the spectrum looks as Figure 7.

```
DSP_SPECTRUM(WaveArray, SpectrumArray, DB, 1.0, FLAT_TOP, 0);
```

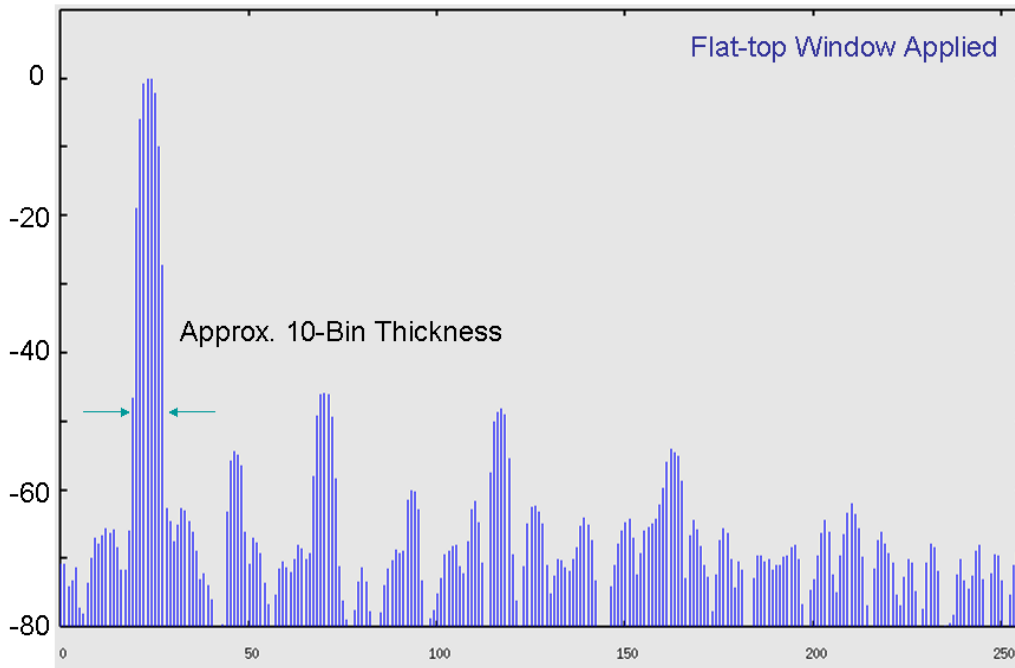


Figure 7: FLAT_TOP Window Applied Spectrum

The tone location becomes fat as approximately 10 bins wide. However, the amplitude is very good as Figure 8 shows. The amplitude error would be expected less than 0.02dB. In many test applications, you need amplitude information only so that FLAT_TOP is very useful for them.

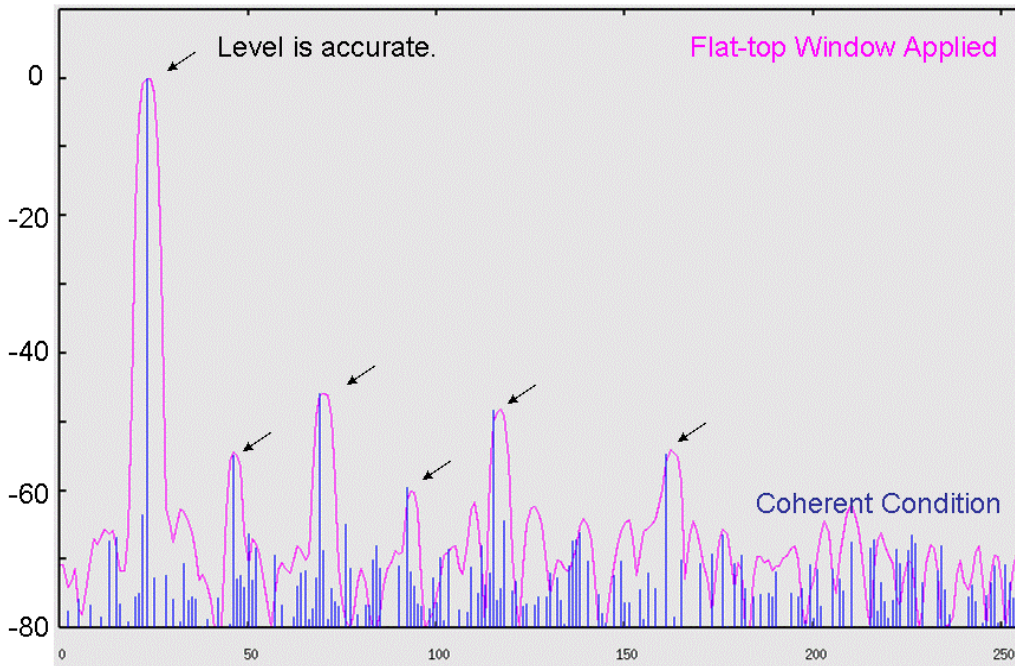


Figure 8: FLAT_TOP Window Applied Spectrum