WAVECREST Corporation

Measuring Low Frequency Attosecond Jitter

Application Note No. 137

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Introduction

In this document, a technique for measuring jitter components that have peak-to-peak amplitude in the attoseconds is discussed. These measurements are made on a *WAVECREST* DTS-207X series with ***Virtual Instrument Signal Integrity™6*** (***VISI6***) software and an HP8648D as the signal source. Plots are included of the data collected.

Overview of Jitter Components[1]

Jitter is a period / frequency displacement of a signal from its ideal location. These displacements can occur in amplitude, phase or pulse width and are generally categorized as either deterministic or random in nature.

Total jitter is the convolution of Deterministic Jitter (DJ) and Random Jitter (RJ).[1] Deterministic Jitter is composed of Duty Cycle Distortion (DCD), Inter-Symbol Interference (ISI), Periodic Jitter (PJ) and Bounded Uncorrelated Jitter (BUJ).

DCD is caused when a data signal has a static duty-cycle error and/or this error varies with time. For example, DCD is caused by errors in the trigger threshold of a circuit and by coupling capacitors in the presence of low frequency content in the data signal.

ISI is caused by a data path propagation delay that is a function of the past history of the data. It is also known as Data Dependent Jitter (DDJ).

Periodic Jitter (PJ) is caused by one or more sine waves and its harmonics. It is typically the result of signal crosstalk.

Like all physical phenomena, some level of randomness-to-edge deviation occurs in all electronic signals. Random Jitter (RJ) is probabilistic in nature and is best modeled by a Gaussian function. Random Jitter is unbounded and therefore directly affects long-term reliability.

Low Frequency Modulation Measurements

The DTS-2077™ uses a comparator-based front end to make a single-shot time measurement. For details of DTS systems, refer to reference [2]. Low Frequency Modulation is a special function of the ***VISI6*** software. It measures a burst of *n* input events and the associated time jitter. This gives one jitter measurement sample. To get a series of jitter measurement samples, this measurement is continued for a burst of samples. Then an FFT is applied to the time jitter series generating a jitter spectrum in the frequency-domain.

The FFT spectrum noise floor is affected by the spectral resolution of the Time Digitizer function. In other words, the smaller the spectral resolution, the lower the jitter noise floor and vice versa. For a given maximum frequency, the larger the burst sample, the smaller the spectral resolution. In ***VISI6*** this value is input into the *Minimum Data Points* box. The largest burst sample that this software tool can make is 16384. However, increasing this number will increase the measurement time.

The number of n events determines the Nyquist frequency. The longer the *n* events measured, the longer the sampling interval and the smaller the Nyquist frequency and vice versa. In the ***VISI6*** software, the Nyquist frequency is input in the *Maximum Freq (kHz)* box.

Setup

The setup is shown in Figure 1. The RF output of an HP8648D 4kHz to 4GHz signal generator is connected to the Channel one input of the *WAVECREST* DTS-2077. The Cal1 output of the DTS-2077 is connected to the ARM2 input of the DTS-2077. The internal 1kHz FM modulation of the HP8648D is used as the modulation source. The ***VISI6*** clock tool "Low Frequency Modulation" is used to do the analysis. The ***VISI6*** tools setting were 1.5kHz for the *Maximum Freq* and 16384 for the *Minimum Data Points*. Also, 32 FFT were averaged.

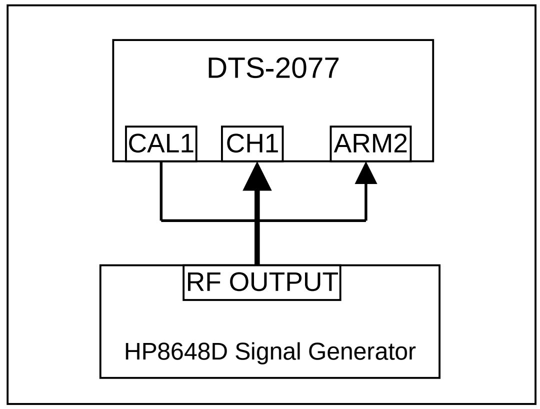

Figure 1 - Experiment Setup

Measurement Results

Using the above setup, several modulation amplitudes were used to get results. The HP8648D has an internal 1kHz modulation source that can be frequency modulated (Fm) in 10 Hz increments. The *WAVECREST* DTS-2077 reports the peak amplitude of the modulation in seconds. The equation for converting Fm in Hz to jitter in seconds is shown below.

$$TJ_{Pk} = \frac{fm}{f_0^{\,2}} \qquad \textbf{(a)}$$

For example, if you have an offset frequency (FM) of 100Hz and a carrier frequency (f_0) of 200MHz the total jitter peak amplitude (TJ_{pk}) would be 100 divided by 2E8 squared or 2.5E-15 seconds or 2.5 femtoseconds (fs). Figure 2 shows the plot for this exact setup. The amplitude measured by the DTS-2077 is 2.521fs. This is less than a 1% error.

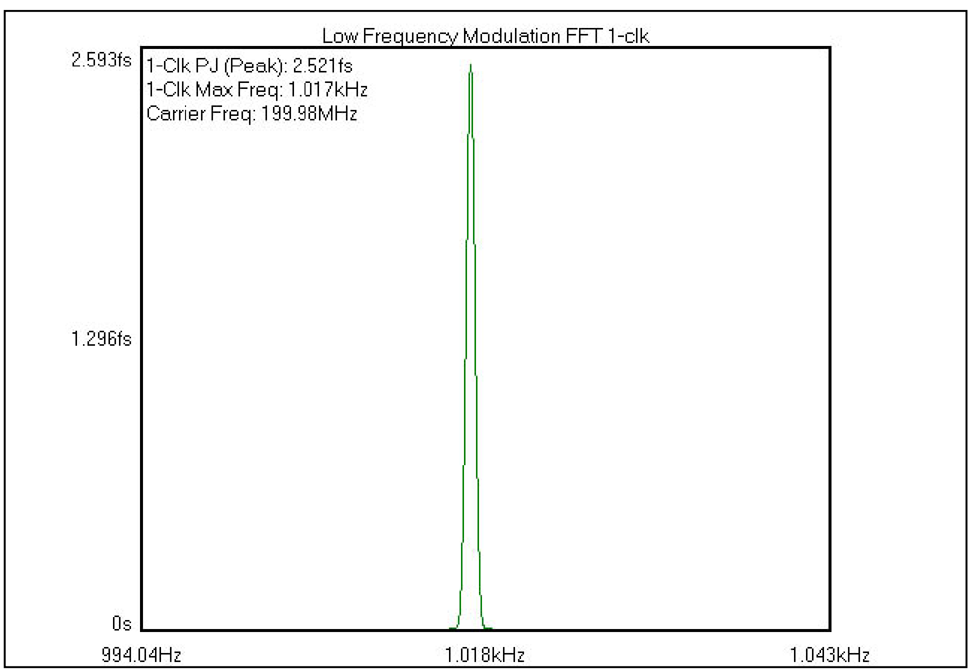

Figure 2 - 200MHz carrier, 1kHz modulation, 100Hz amplitude.

In the next example, the modulation frequency was decreased to 10Hz. The same carrier frequency and modulation frequency were used. Figure 3 illustrates the results. Using Equation (a) we get a modulated amplitude of 2.5E-16 or 250 attoseconds (as). Figure 3 shows that we actually measured 280.6as. This represents an error of 12.24%. But the delta (30.6as) is close to the delta in Figure 2 (21as). This error could be attributed to bleed-through in the HP's modulation circuitry. To verify this the modulation frequency is set to 0Hz. This is shown in Figure 4.

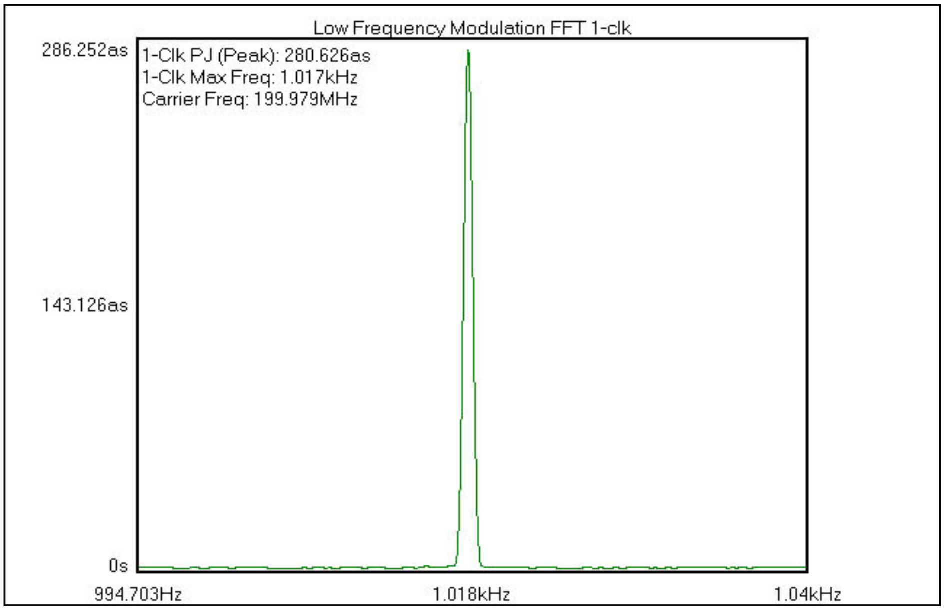

Figure 3 - 200MHz carrier, 1kHz modulation, 10Hz amplitude.

In this experiment the modulation amplitude that is expected is 0as. But, as Figure 4 shows, there is a peak with amplitude of 18.25as at 1.017kHz. This is the bleed-through of the modulation circuitry of the HP8648D.

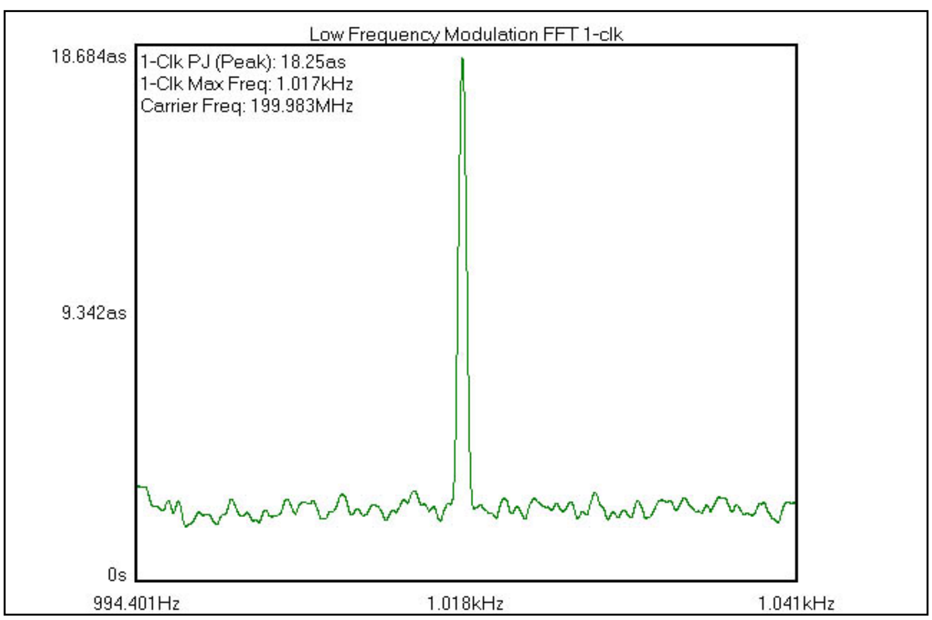

Figure 4 - 200MHz carrier, 1kHz modulation, 10Hz amplitude.

Next, the modulation circuitry is turned off. Figure 5 shows the FFT for this experiment. The modulation component is now completely gone.

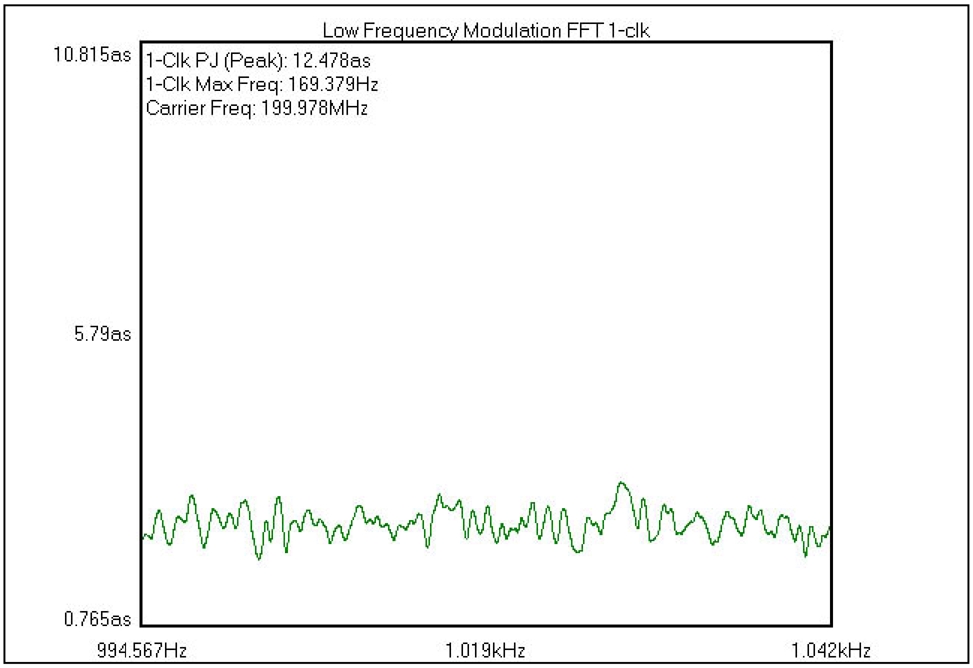

Figure 5: 200MHz carrier, 1kHz modulation switched off.

So, if we estimate the modulation circuitry bleed-through to be 18.25as and subtract it from the previous measurements, we get an error of less than 0.2% for figure 2 and an error of less than 5% for figure 3 from the calculated value to the actual measured value.

Conclusion

This paper has shown the ability of the DTS-207X series instrument to measure low frequency jitter modulations with peak-to-peak amplitudes in the attoseconds using ***VISI™6*** software. Jitter modulations as low as 18.25as have been measured with FFT noise floors around 2as. It was shown that this correlated to within 95% of the expected value. Such measurements can be used to quickly identify low frequency modulation signals on clock sources.

<u>Footnotes:</u>

[1] Fibre Channel Methodologies for Jitter Specification, Rev 10, page 30, at ftp:ftp.t11.org/t11/member/fc/jitter_meth/99-151v2.pdf

[2] *WAVECREST* Corporation, "DTS-2077 Product Specification, Rev 3.1", 1998

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