How to measure Spread Spectrum modulation

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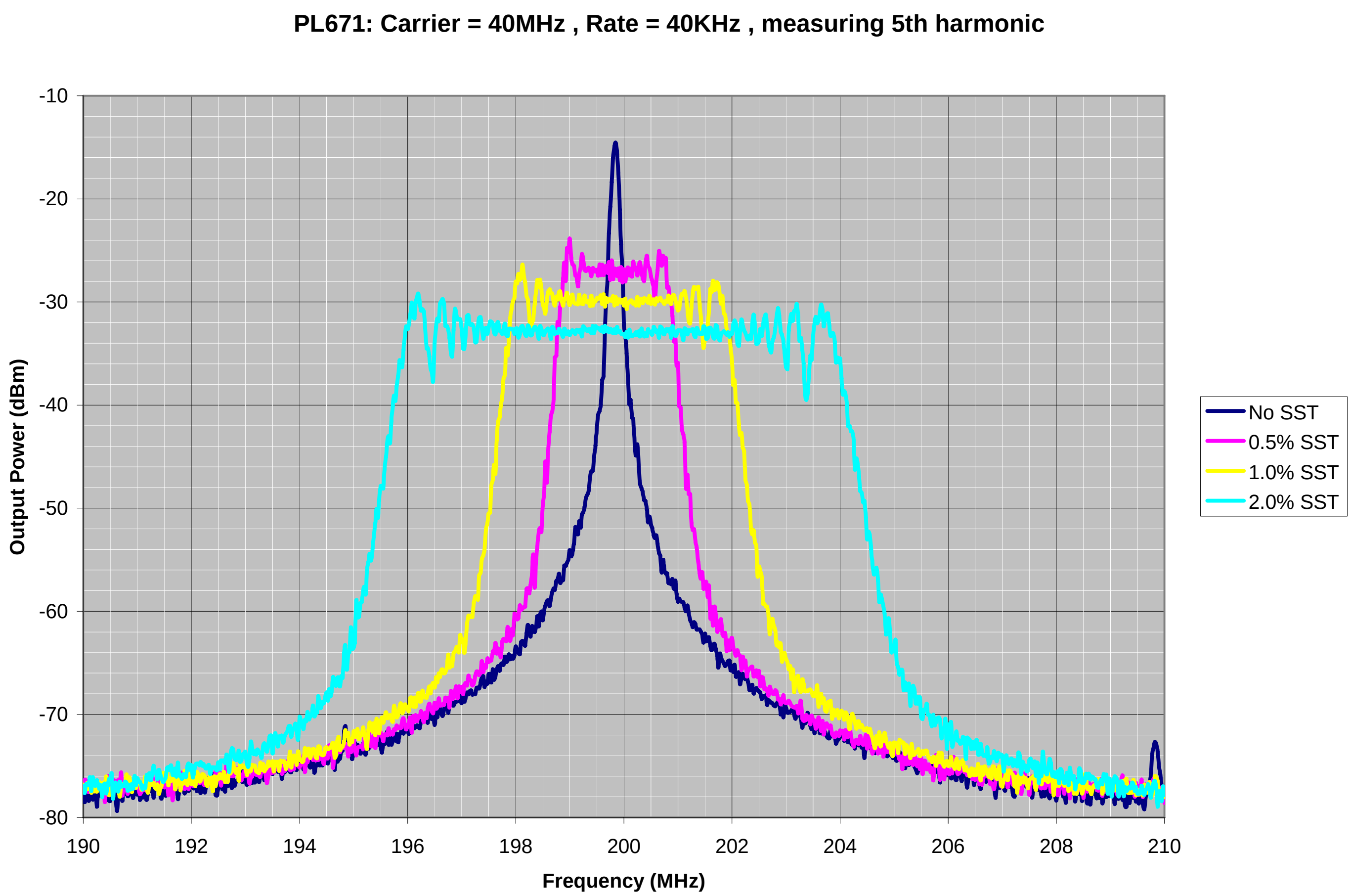
PhaseLink has a number of products that use Spread Spectrum modulation as a means to provide EMI reduction. A simple description of spread spectrum modulation is the movement of the clock output frequency back and forth to spread the RF power of interference caused by the clock output. Without spread spectrum modulation a clock output will have its RF power concentrated in narrow harmonics. These harmonics reach up to a certain level and when they are radiated, the level may increase above an EMI spec. By applying spread spectrum modulation the RF power is spread out and the harmonics become wider. The result is that the harmonics reach up to lower levels in the frequency spectrum even when the total amount of RF power is the same. Below is a frequency spectrum plot of the 5th harmonic of a 40MHz square wave with different amounts of spread spectrum modulation.

Figure 1: Frequency Spectrum with Spread Spectrum modulation

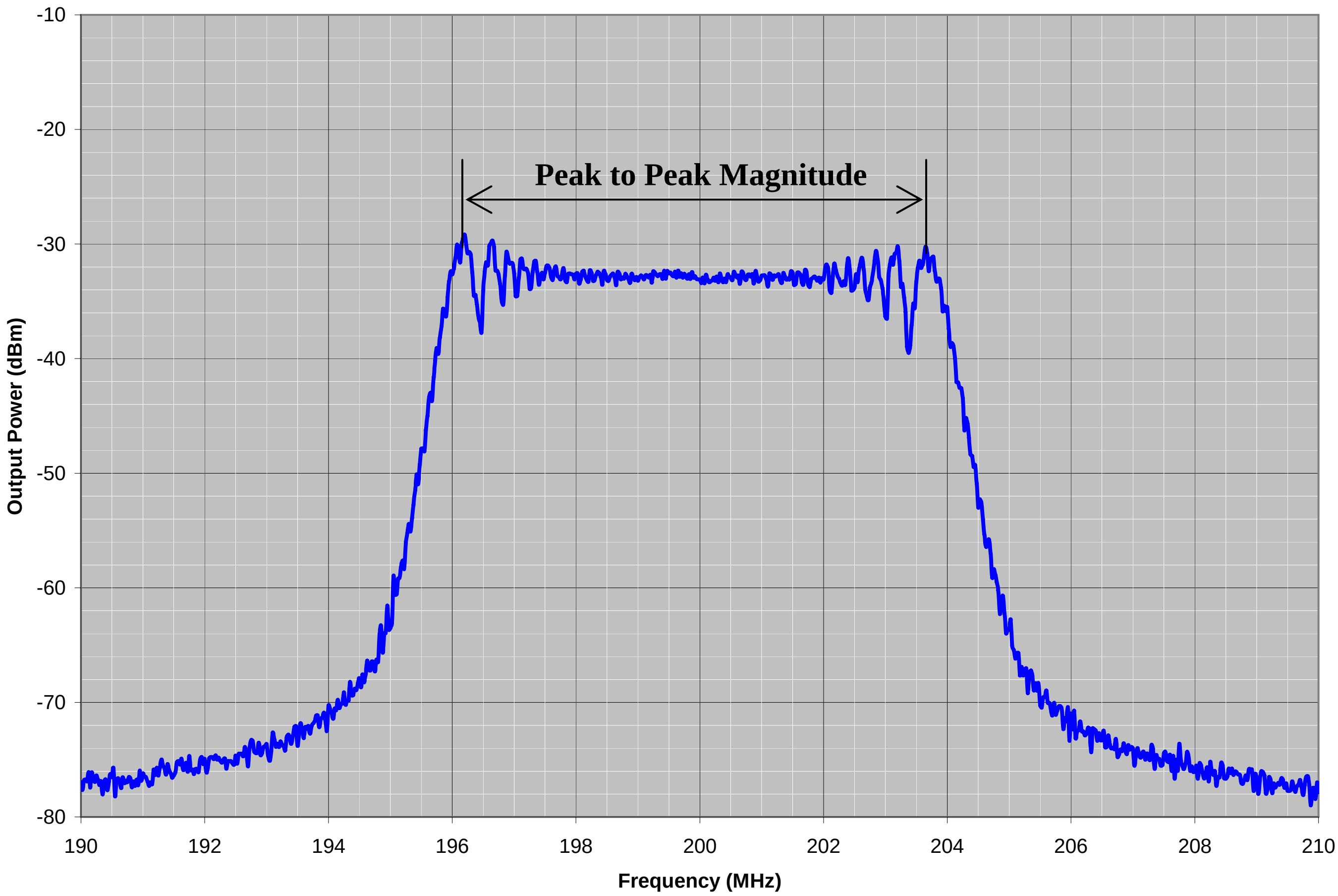


Spread Spectrum Measurement with a Spectrum Analyzer

Even though the amount of dB reduction in the frequency spectrum is the goal of spread spectrum this is usually not the parameter that is measured to verify the amount of modulation. The parameter that is measured is the modulation magnitude in percent. The magnitude is the amount of frequency change back and forth. Figure 1 was measured with a Spectrum Analyzer. You can measure the magnitude by the width of the harmonic in the Spectrum Analyzer graph. For example the width at ±2% modulation is 196MHz~204MHz or 200MHz ±4MHz. The 4MHz width is indeed 2% of the 200MHz carrier.

The proper measurement technique with a spectrum analyzer is to measure the frequency span between the two outer peaks of the harmonic. Figure 2 shows an example.

Figure 2: SST Magnitude measurement with Spectrum Analyzer:

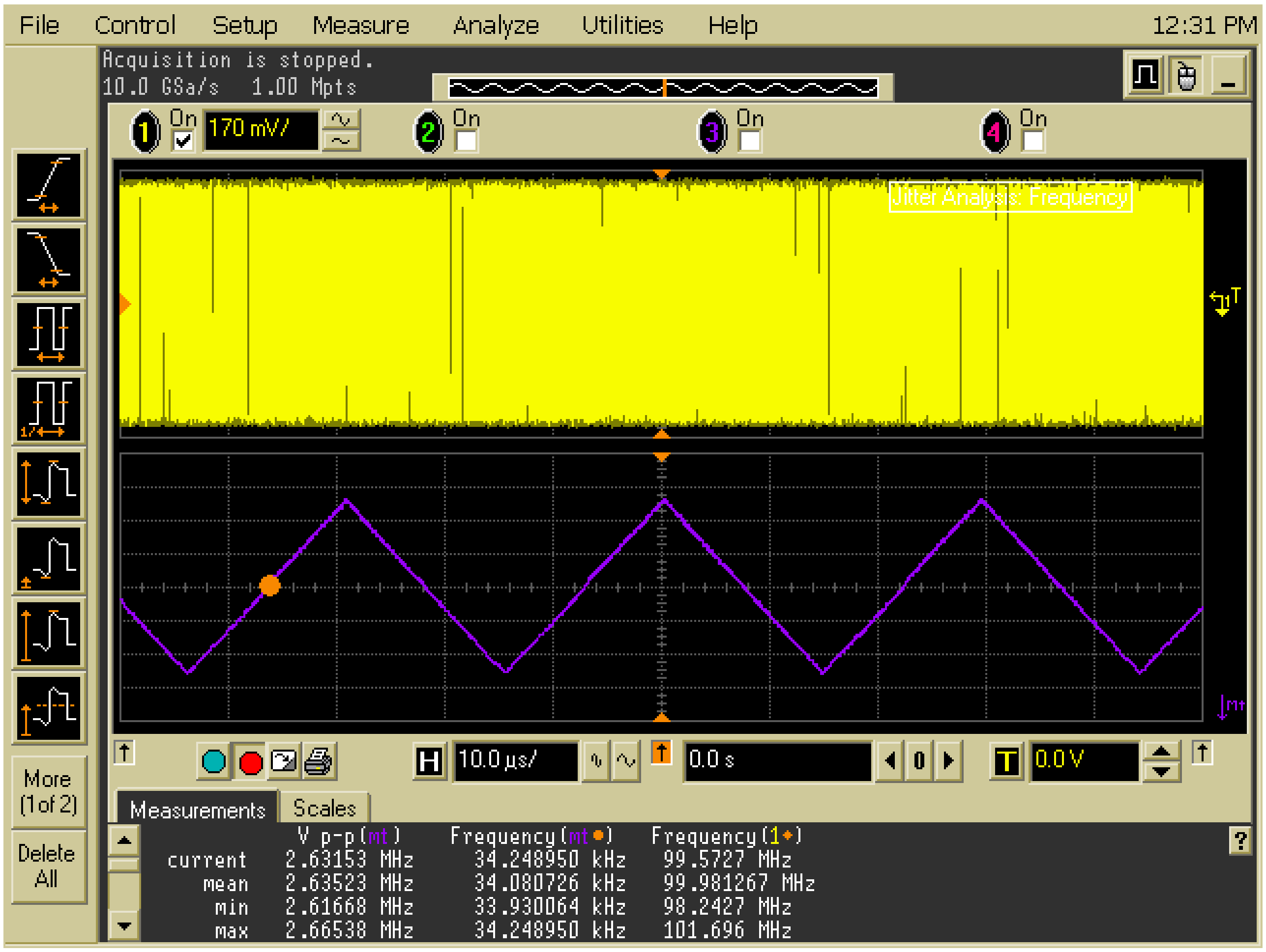


The measurement can be done at the carrier frequency or at one of the harmonics. At each harmonic the ratio between magnitude and center of the harmonic should be the same.

Spread Spectrum Measurement with a Digital Oscilloscope

Digital Oscilloscopes have all kinds of features these days. The Jitter Trend feature can be used to measure the spread spectrum modulation. Below is a screen shot from an oscilloscope.

Figure 2: Digital Oscilloscope measurement



The yellow trace is the clock signal and the purple trace is the result from analysis done inside the oscilloscope. The oscilloscope is essentially plotting the frequency trend of the clock signal and this is precisely what we want to see. In this case the carrier frequency is 100MHz and the oscilloscope is measuring a 2.635MHz peak-to-peak variation around the carrier so the magnitude is 2.6%-pp or ±1.3%. The oscilloscope can also measure the modulation rate, in this case 34KHz. This is an advantage over the measurement with a spectrum analyzer where you can not see the modulation rate. The modulation rate is the rate at which the frequency is moving back and forth. The rate is usually set between 30KHz and 40KHz.

The frequency trend measurement can have different names depending upon the oscilloscope manufacturer. It can be named “Jitter Trend” (Agilent) or “Jitter Track” (LeCroy).

The oscilloscope is most suited for an automated measurement because, as you can see in above picture, the values needed can be displayed as test results on the screen. These values can be read with a computer through the GPIB or other bus.

Miscellaneous Spread Spectrum Measurements

Fast Frequency Counter: There are fast frequency counters available that can do a series of very fast frequency measurements in one burst measurement. For example when you measure a series of frequencies every 1µs then you have 30 measurements inside one modulation cycle at 33KHz rate. This should allow you to reconstruct the triangular modulation waveform to determine its properties.

Time Interval Analyzer: This equipment works similar to the fast frequency counter. The TIA will usually measure pulse or cycle widths but this can be converted to a frequency quite easy. PhaseLink uses TIA's in volume production to measure spread spectrum modulation properties.

Modulation Analyzer: Modulation analyzers have been around for a long time and one of these old boxes (HP8901) can be very useful in testing spread spectrum modulation. The box will most likely output the demodulated signal so any oscilloscope that can measure up to about 100KHz can show the modulation wave and measure its properties. The box may even be able to display the frequency modulation index which is identical to the magnitude. For example when the carrier is 100MHz and the modulation index is 2MHz then the spread spectrum magnitude is ±2%.

Peak-to-Peak Period Jitter: Spread Spectrum modulation is an extreme form of deterministic period jitter. It is possible to determine the modulation magnitude simply by measuring the peak-to-peak period jitter. For example a 100MHz carrier with ±2% modulation magnitude will have clock cycle widths between 9.8ns and 10.2ns so the period jitter caused by the modulation is 400ps peak-to-peak. Unfortunately the circuit (PLL) that makes the spread spectrum clock will have significant period jitter of its own, possibly up to 100ps peak-to-peak, so this method is not very accurate.