SiTime Spread Spectrum Clock Oscillators

1 Introduction

With increasing processor speeds and data rates in today's electronic systems, electromagnetic Interference (EMI) has become a major challenge for designers. EMI generated in one device can impede the operations of other electronic devices in its vicinity.

The clock generator is often the largest contributor of EMI in a system. The frequency spectrum of square-wave clocks consists of a fundamental tone as well as a collection of higher harmonics. Filtering, shielding, and good PC layout practices can limit the EMI in a system, but they add cost and consume valuable board space. An alternate approach is to reduce the noise generated by the clock. By modulating the clock's frequency slowly over time, the peak spectral energy in both the fundamental and harmonic frequencies will be reduced. This reduction is useful because the FCC uses the peak power within a specific bandwidth, typically 100 KHz to determine the EMI.

2 Spread Spectrum Benefits

The output of a spread spectrum clock such as the SiT9001, SiT9002, and SiT9003 are conditioned by modulating its PLL with a 32 kHz triangular wave shown in Figure 1.

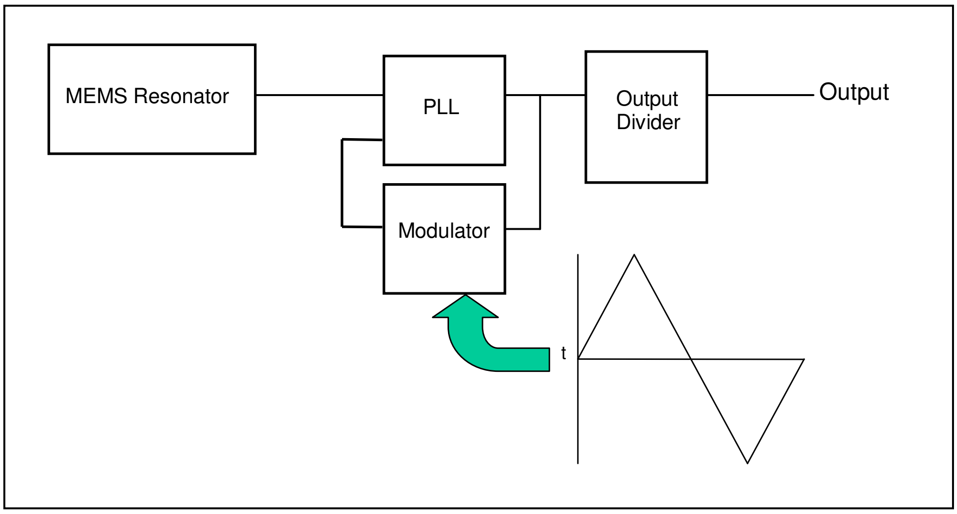

Figure 1. Modulating the PLL with a Triangular Wave

The spreading profile contains a number of user selectable parameters:

1. Spreading type: center spread or down spread
2. Spread percentages (or modulation limits) -
   - Center spread : ±0.25%, ±0.5%, ±1.0%, ±2.0%
   - Down spread : -0.5%, -1.0%, -2.0%, -4.0%

If the clock frequency is 100 MHz, selecting a ±1.0% center spread will limit the output from 99 MHz to 101 MHz. Similarly, choosing a -2% down spread will cause the output to range from 98 MHz to 100 MHz.

The triangular wave was chosen as the modulating signal because it has a reasonably flat power density in the frequency domain. Figure 2 shows the spectrum plot of a non-spreading clock and that of a spread spectrum clock. By intentionally spreading the energies stored in a non-spreading clock over a small range of frequencies, a reduction in spectral amplitude is achieved.

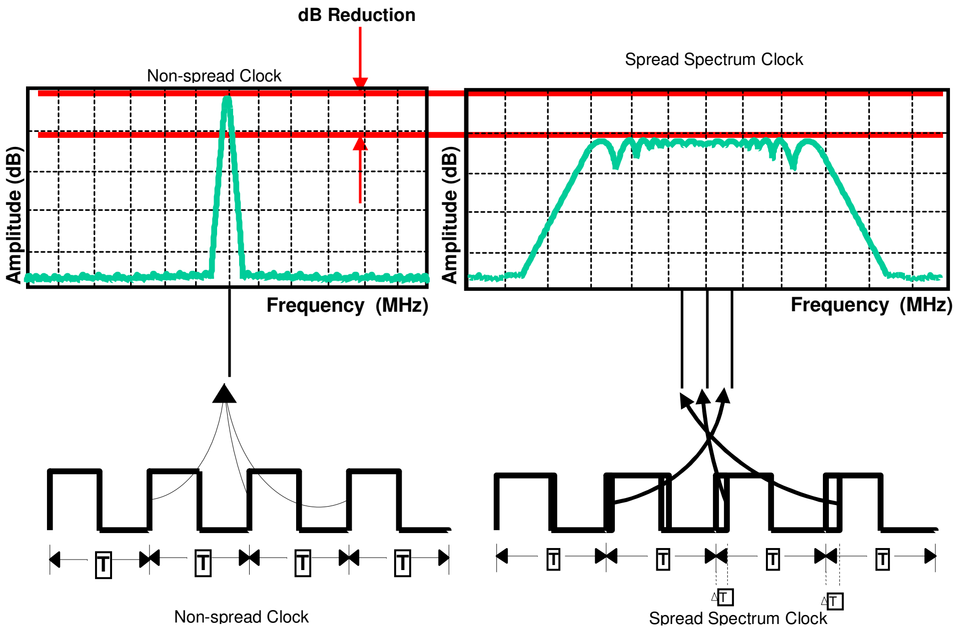

Figure 2. Spectrum plots of a non-spreading clock and a spread spectrum clock as measured by a spectrum analyzer with a 100 KHz resolution bandwidth

To get a better understanding of the noise reduction benefits of a spread spectrum clock, we used a spectrum analyzer to measure the peak power of a 125 MHz SiT9001 with and without the spreading feature enabled. In this test, a down spread of -2% was chosen. Figure 3 is the output of the spectrum analyzer. With the spreading feature turned on, the EMI reduction to the average level of the spread spectrum is 13 dB (marker 3 – marker 1) while the peak to peak reduction is 11 dB (marker 3 – marker 2).

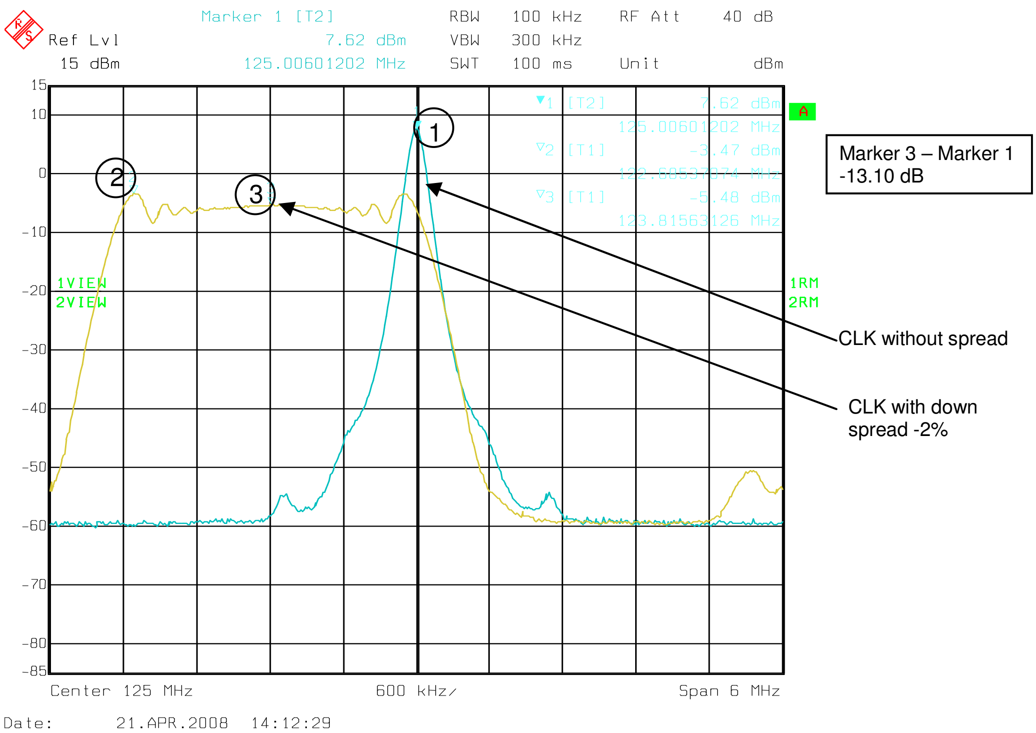

Figure 3. Noise Reduction Benefits of a Spread Spectrum Clock

3 Estimation of EMI Reduction in Spread Spectrum Clocks

It is often desirable to be able estimate the EMI reduction on paper without resorting to laboratory measurements. The user can make such estimations using the following equation:

$$\text{EMI reduction (dB)} = 10\log\frac{|S|fc}{RBW} \qquad \text{Equation 1}$$

where S is the peak-to-peak spread percentage, fc is the carrier frequency and RBW is the resolution bandwidth of the spectrum analyzer. For clock measurements, the RBW is typically set to 100 KHz.

We can verify the results from equation 1 against the measured values. With the SiT9001 operating at 125 MHz and a down-spread of 2%, the calculated EMI reduction is:

$$\text{EMI reduction} = 10 \log (0.02 \times 125\text{MHz})/100 \text{ KHz} = 14 \text{ dB}$$

The calculated value is close to the measured peak-to-average value of 13 dB. However, it is 3 dB higher than the peak-to-peak value of 11 dB due to the ripples in the spread spectrum. The user should keep this in mind when estimating the peak-to-peak EMI reduction with these equations.

To better analyze the accuracy of the above equations, we measured the EMI reductions of a SiT9001 at 3 different down-spread percentages and compared them against the calculated values. The results are shown in Figure 4. The dash lines represent the calculated values whereas the solid lines are the measured peak-to-average values using a Rohde & Schwarz spectrum analyzer. From the figure, we can see that the calculated values generally stay within ± 1 dB of the measurements.

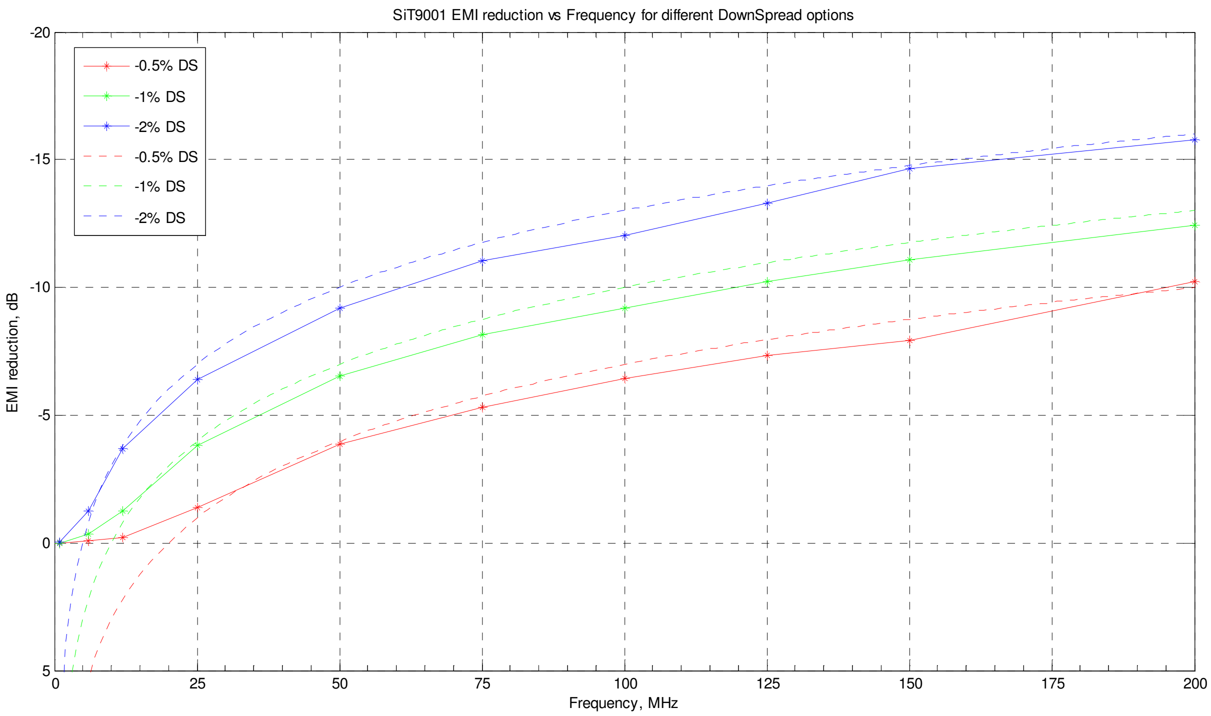

Figure 4. Calculated EMI Reductions vs Measured Values

4 The Effects of Spread Spectrum on Clock Harmonics

FCC compliance encompasses the fundamental as well as the harmonic frequencies of a clock. Sections 2 and 3 described the effects of spread spectrum on the fundamental frequency, but how about the harmonics? Fortunately, the EMI reduction benefits also apply to the harmonics.

From equation 1, we can see that the amount of EMI reduction is directly proportioned to the frequency. To verify this, we measured the spectrum of a 100 MHz SiT9001 with and without 2% down-spread at its fundamental frequency (100 MHz), at the third harmonic (300 MHz), and at the fifth harmonic (500 MHz). The results are shown in Figures 5 and 6.

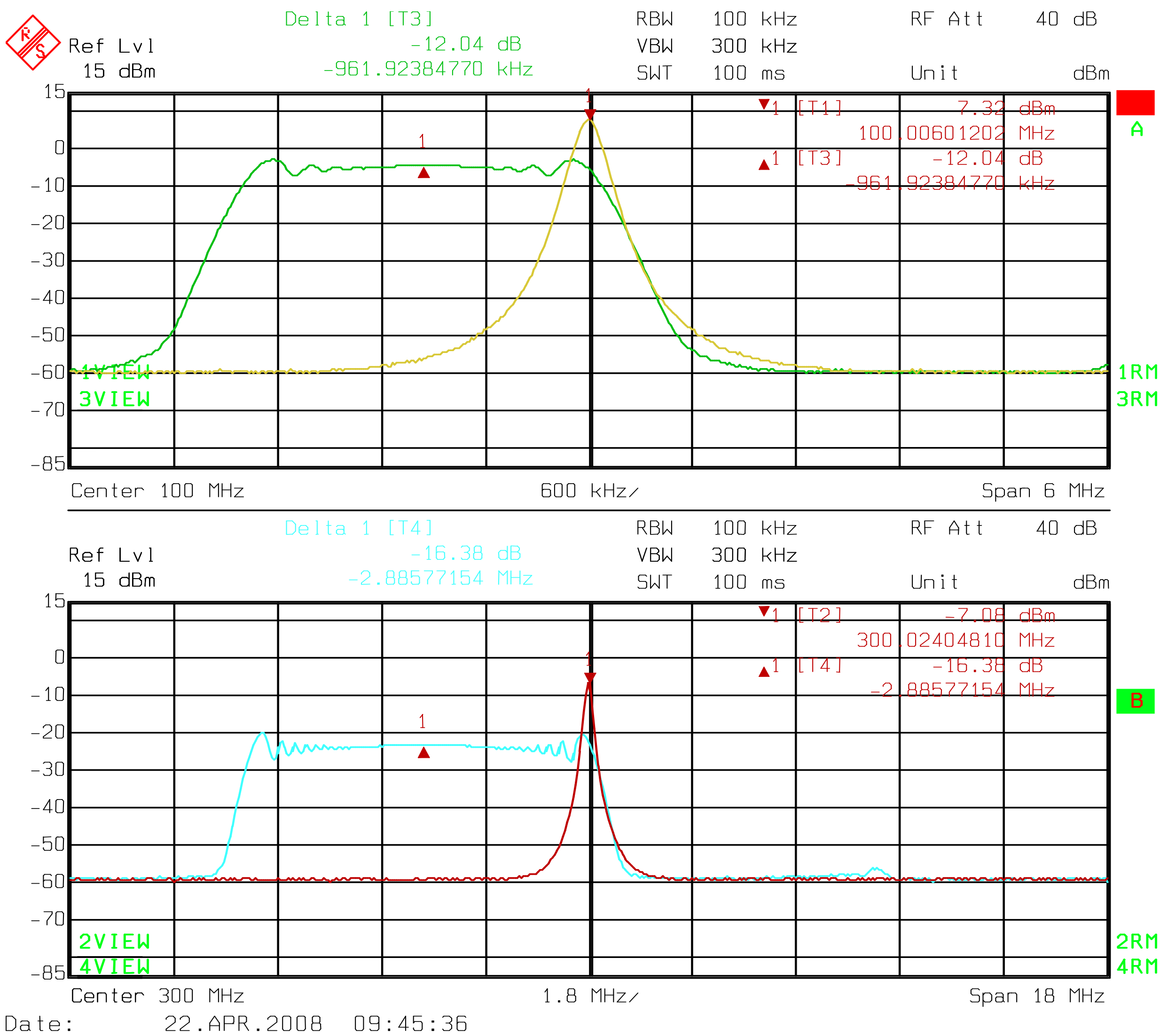

Figure 5. spectrum plots of a 100 MHz SiT9001 at 100 MHz and 300 MHz

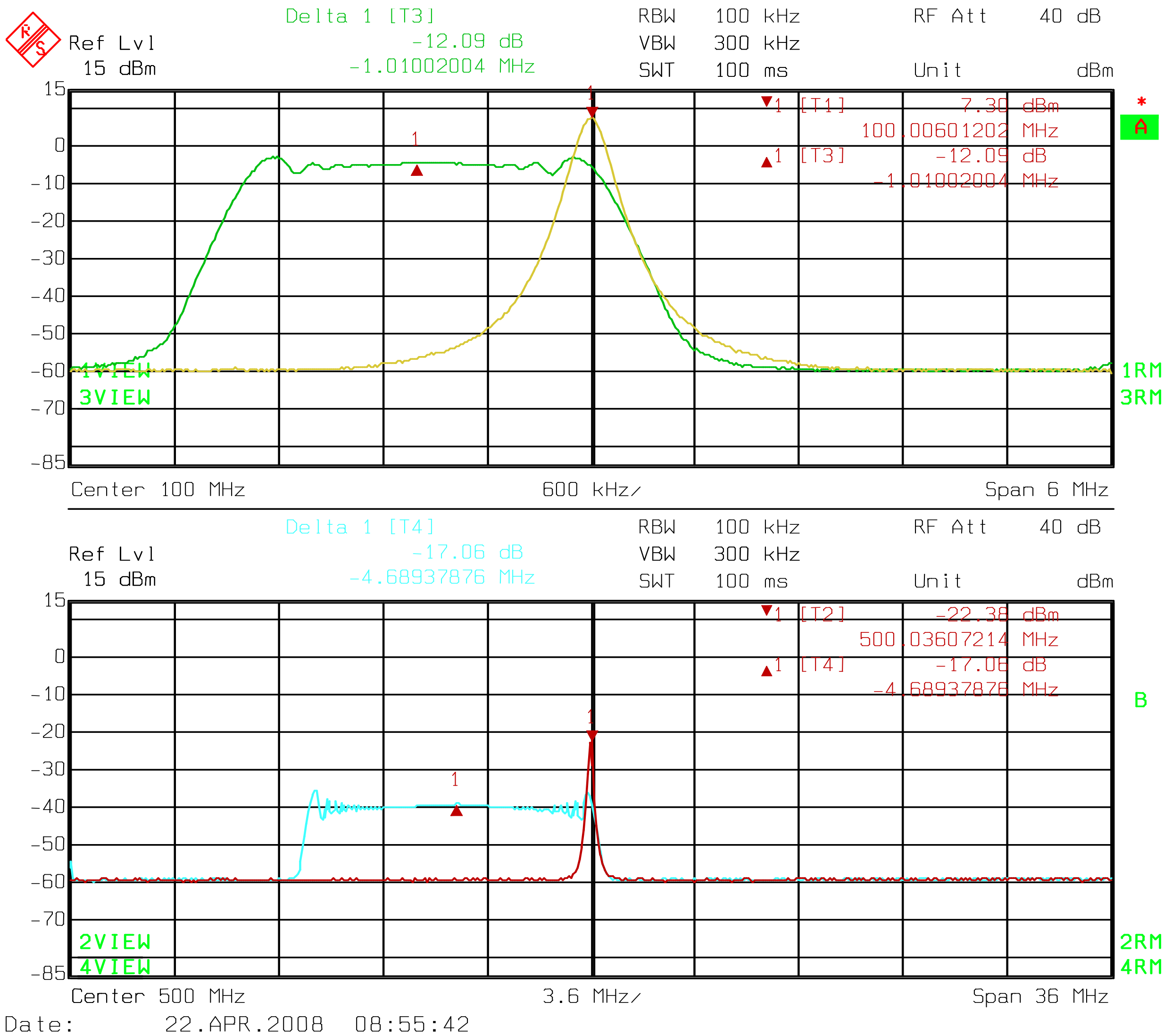

Figure 6. spectrum plots of a 100 MHz SiT9001 at 100 MHz and 500 MHz

The EMI reduction from spread spectrum at the fundamental frequency (100 MHz) is 12.09 dB. It increased to 16.38 dB at the third harmonic (300 MHz) and 17.06 dB at the fifth harmonic (500 MHz). In other words, spread spectrum reduces EMI for all the frequency components in the clock output.

5 Conclusion

The spread spectrum feature in SiTime clocks offer excellent EMI reduction at its outputs, making them invaluable in noise sensitive applications.

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