Bunch Fourier Transform with Noise, and with Subharmonic Laser Modulation

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The following FFT plots show the frequency domain analysis of a 400-MHz beam pulse microstructure modulated by a 100-MHz mode-locked laser, with various amounts of random micropulse amplitude jitter.

$t := 1 .. 4095$

$k_t := 4 \cdot \text{round}\left(\left(\frac{t+3}{4}\right)\right)$ $\quad m_t := 16 \cdot \text{round}\left(\left(\frac{t+3}{16}\right)\right)$

$A_t := \delta(t+3, k_t)$ $\quad B_t := \delta(t+3, m_t)$

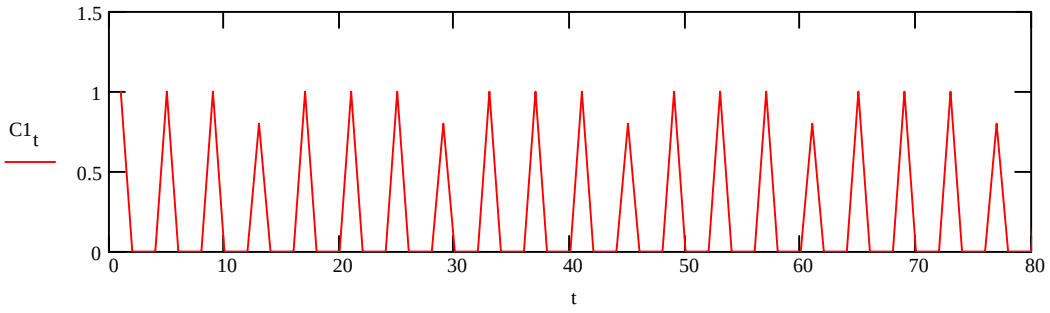
$C1_t := (1 + 0.0001 \cdot (\text{rnd}(1) - 0.5)) \cdot (A_t - 0.2 \cdot B_t)$ $\quad \text{length}(C1) = 4.096 \cdot 10^3$

$C2_t := (1 + 0.0001 \cdot (\text{rnd}(1) - 0.5)) \cdot (A_t - 0.01 \cdot B_t)$

$C3_t := (1 + 0.001 \cdot (\text{rnd}(1) - 0.5)) \cdot (A_t - 0.001 \cdot B_t)$

$C4_t := (1 + 0.01 \cdot (\text{rnd}(1) - 0.5)) \cdot (A_t - 0.0001 \cdot B_t)$

Time structure of 400-MHz micropulses, showing 20% laser modulation at 100 MHz



$N := 4096$ $\quad j := 0 .. \frac{N}{2}$

========== Fast Fourier Transforms ==========

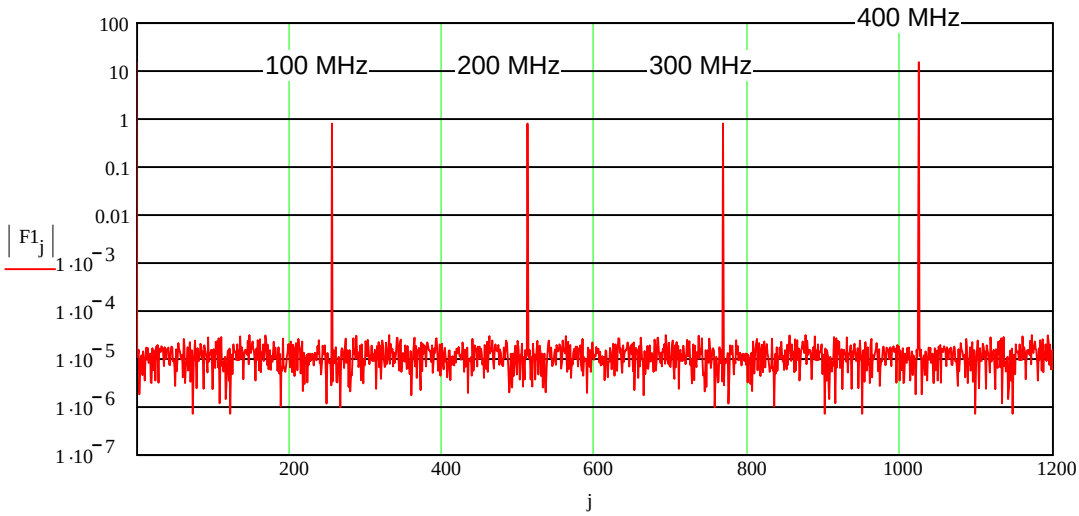
$F1 := \text{fft}(C1)$ FFT of C1 $\quad \text{length}(F1) = 2.049 \cdot 10^3$

$F2 := \text{fft}(C2)$

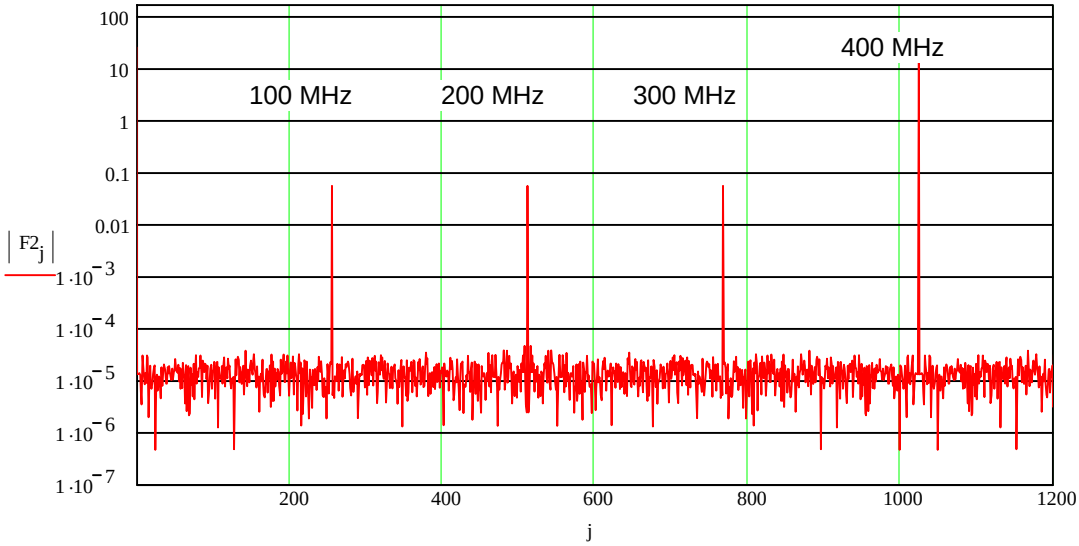
$F3 := \text{fft}(C3)$

$F4 := \text{fft}(C4)$

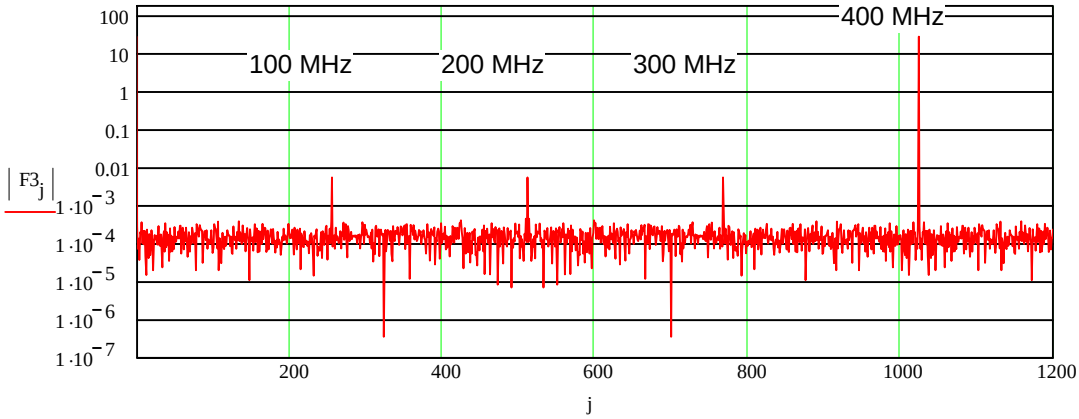
20% laser modulation, 0.01% random noise



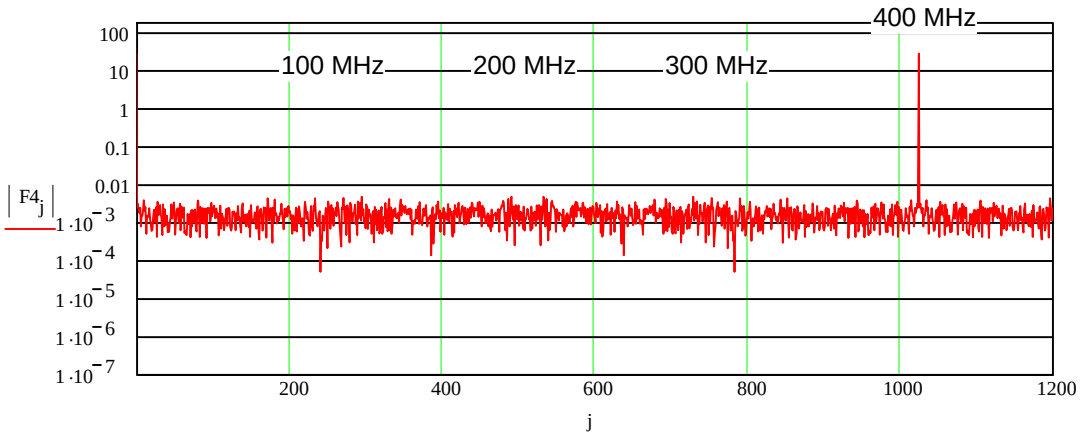
1% laser modulation, 0.01% random noise



0.1% laser modulation, 0.1% random noise



0.01% laser modulation,   1% random noise



Where's the signal?