Modulation Analysis - FM

Using Jitter And Timing Functions To Analyze FM signals

The LeCroy WaveMaster™ series oscilloscopes incorporating the Jitter and Timing Analysis 2 (JTA2) option are ideal for extracting the modulating waveform from a frequency modulated (FM) signal. The frequency deviation of the carrier, the modulation frequency, and the modulation index can all be determined from the demodulated waveform.

The analysis of a 10 MHz FM signal with a 20 kHz sinewave modulation and 110 kHz deviation is shown in figure 1. The acquired frequency modulated waveform is shown in the upper trace (C2). The JTA2 function track of frequency at level (freq@lv) is used to obtain a function of instantaneous frequency vs. time shown in trace F1. The sinusoidal modulation is clearly evident. Averaging has been applied to improve the signal to noise ratio utilizing the WaveMaster's dual math function. Measurement parameters read the mean frequency (P1), peak to peak frequency range (P2), modulation frequency. The parameter P5 uses parameter math to compute the modulation index. This function takes the ratio of the peak to peak frequency variation (P2) divided by twice the modulation frequency (P4).

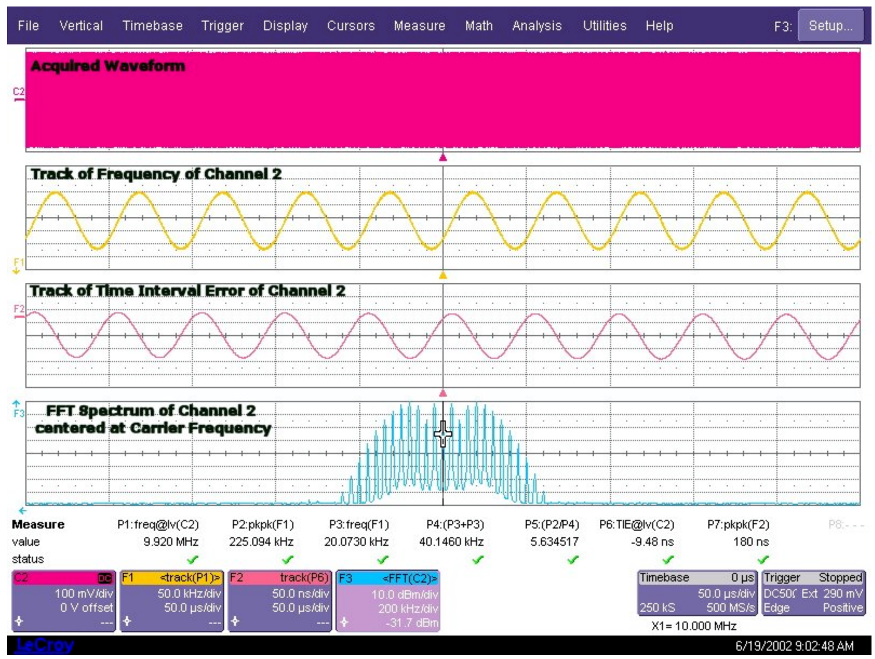

Figure 1 Analysis of an FM signal using both Track of frequency at level and the FFT

The lower trace, F3, in this waveform is the averaged fast Fourier transform (FFT). In this case it has been expanded about the 10 MHz carrier and shows the sideband structure of the FM waveform with a horizontal scale factor of 200 kHz/division and a resolution bandwidth (Δf) of 2 kHz.

The trace F2 is the track function of time interval error (TIE). The TIE function compares the waveform threshold crossing to a reference frequency and produces a plot of time error vs. time. This function is proportional to the instantaneous phase of the acquired waveform.

Another approach for demodulating the FM waveform is to measure the phase variation of the signal as a function of time and then scale and differentiate the phase to obtain the frequency variation. This approach is illustrated in figure 2. The instantaneous phase is obtained using the track of time interval error (TIE) function shown in trace F1. The rescale math function is used to convert from time interval error to phase in radians. The multiplicative constant required to convert time interval error in units of time to radians is $2\pi f_c = 6.28 * 10 * 10^6$, where f_c is the carrier frequency. This scale factor is applied in trace F2.

The rescaled phase function can now be differentiated to obtain the instantaneous frequency as a function of time. This is accomplished in F3. Note that in order to reduce the generation of noise in the differentiation process the number of points in the calculation is reduced by a factor of 100:1 using the sparsing function. Again, the use of the dual math function allows both operations within a single trace.

Trace F3 is rescaled in trace F4 to add the nominal frequency (10 MHz) which was removed in the time interval analysis and rescale the data to read in units of frequency. The multiplicative constant is 1/2π (0.159) and the additive constant is the average carrier frequency. The parameters in figure 2 are the mean TIE(P1), the peak to peak phase deviation (P2), the peak to peak frequency deviation(P3), the maximum frequency (P4), the minimum frequency (P5), and the modulation frequency (P6)

The second technique is more effective for FM analysis on waveforms with smaller frequency deviations. The time interval error measurement usually exhibits a higher signal to noise ratio than the track of frequency at level.

It should be obvious that the JTA2 functions, augmented by the full featured math processes available in LeCroy digital oscilloscopes, allow users to extract both frequency and phase variations as functions of time. These functions serve as the basis for modulation analysis within the scope.

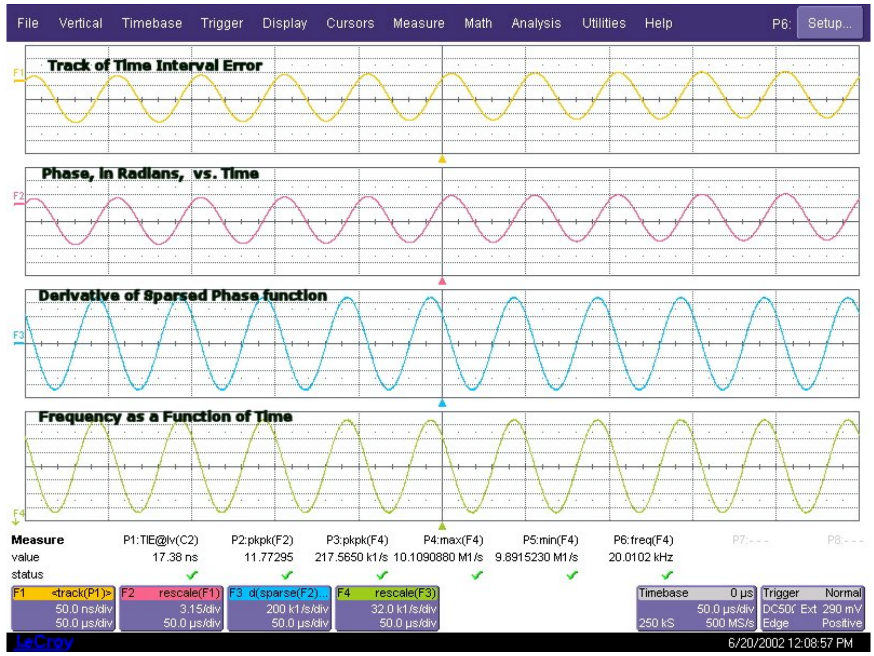

Figure 2 – Deriving the modulation waveform using the track of time interval error function