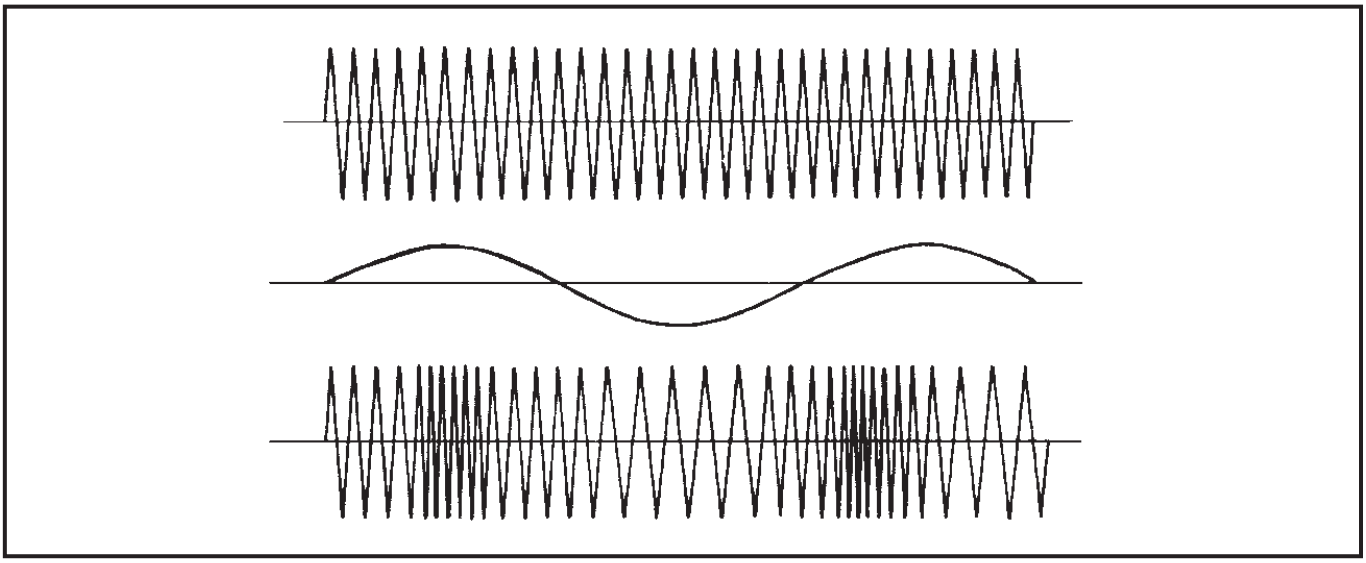
Analysis of FM-modulated signals



Background

A carrier wave is *modulated* when used to carry signal information. Maybe the simplest modulation scheme is just switching the carrier on and off according to a special code, a technique used with Morse code in the early days of telegraphy. Other "classical" modulation principles are frequency modulation (FM) and amplitude modulation (AM).

Unlike for AM, oscilloscopes can not be used to characterize FM-signals. Simply because a FM-signal has a constant amplitude but varies the frequency. And the strength of oscilloscopes is to view *amplitude* variations over time and *not frequency* variations over time.

An excellent solution for viewing frequency changes over time, like for example FM-signals, is the modulation domain analysis package; the CNT-81 and TimeView^{TM}.

Measurement setup

An FM-source was set-up in the following way. The carrier frequency was a 10.7 MHz sine wave with approx 1V amplitude. The carrier was modulated with a square-wave modulation signal of 11.5 kHz. The frequency deviation was approx 700 kHz, corresponding to a deviation of approx. 7% of the 10.7 MHz carrier.

Voltage vs time graph

Using waveform capture mode in TimeView, the time domain picture is seen in figure 1. This voltage vs time graph tells you that the frequency is varying and that minimum period is approx 100 ns, corresponding to approx 10 MHz.

Frequency vs time graph visualizes modulation

In the frequency vs time graph in figure 2, the frequency variations are clearly seen. You can read the maximum and minimum frequencies to approx. 11.5 respectively 10.0 MHz. Each modulation cycle seem to be square wave shaped. By using cursors, the modulation period is found to be approx. 87 μs.

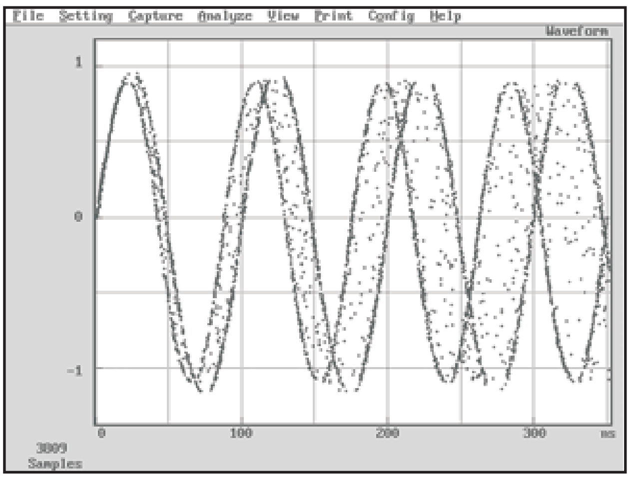


Figure 1 *The voltage vs time graph of a FM-signal (waveform capture mode in TimeView) shows the carrier. You can see that the carrier is a sinewave.*

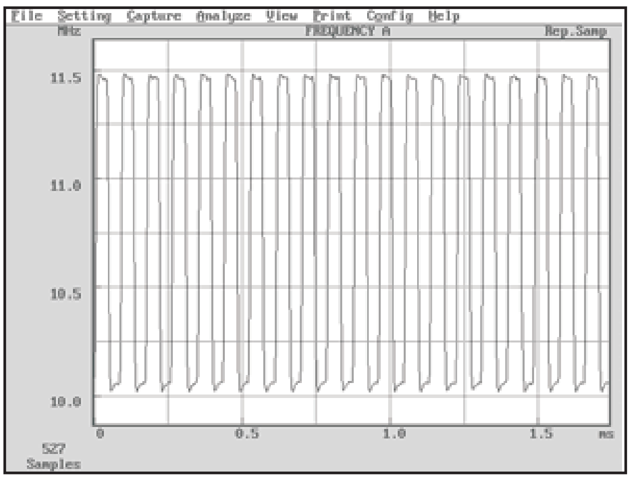


Figure 2 *The frequenncy e vs time graph shows the modulating signal. You can clearly see that the carrier is squarewave modulated.*

Distribution diagram reveals frequency deviation

But TimeView can reveal more about the frequency modulation. Let us examine the distribution of all individual frequency samples from figure 2. This is shown in figure 3.

The box with the standardly calculated statistical parameters shows a carrier frequency (mean value) of 10.76 MHz, a maximum positive frequency deviation of 11.48-10.76 = 0.72 MHz and a negative frequency deviation of 10.76-10.02 = 0.74 MHz.

Now let us look at the shape of the histogram. The samples are concentrated at the very low end (around 10.06 MHz) and at the very high end (around 11.47 MHz). See the two cursors in figure 3 at the two dominant bars in the histogram.

The shape of the diagram is typical for a square wave modulation. The carrier jumps quickly between a “low” and a “high” frequency. And very few samples are taken in between, just as the histogram shows.

FFT-function reveals modulation frequencies

Figure 4 shows FFT-processing of the frequency versus time graph from figure 2. The result is a spectrum of frequencies modulating the carrier frequency.

The largest peak in this FFT-diagram represents the carrier, which by definition is the frequency without any modulation. That’s why the carrier is found at a modulation frequency of 0 Hz. One cursor is positioned at the carrier peak, showing “y=10.76 MHz”. See figure 4.

The other cursor is positioned at the major modulation frequency, which in figure 4 is found to be 11.5 kHz.

What more conclusion can be drawn from figure 4? Well, you may notice that the modulation peaks are found at the following frequencies:

11.5 kHz, 34.5 kHz, 57.5 kHz, ... They relate as 1:3:5 etc. The modulation frequency components are *odd multiples* of the fundamental modulation frequency of 11.5 kHz, which is characteristic for the frequency spectrum of square waves.

Conclusions

TimeView provides 4 different presentation modes, that can be used to analyze and quantify FM.

The voltage vs time graph (figure 1), that is the typical oscilloscope mode, can reveal a varying frequency at a constant amplitude, that is just an *indication* of an FM-signal. This is how far we can come with oscilloscope technology.

The frequency vs time graph (figure 2) gives a clear picture of the periodic frequency variations, i.e. *the modulation*. From this graph you get a quick estimate of carrier, deviation, modulation frequency and modulation signal shape.

The distribution histogram (figure 3) quantifies the carrier frequency and frequency deviation.

The FFT-diagram (figure 4) quantifies carrier and modulation frequency.

All these findings are very consistent across the various presentation modes. The square wave shape from figure 2 is supported by the shape of the histogram and the modulation frequencies (odd harmonics) in the FFT-diagram. The carrier is found to be 10.76 MHz in both the histogram and FFT-diagram. And the modulation period of approx 87 μs from figure 2 corresponds to the 11.5 kHz fundamental modulation frequency, found in the FFT-diagram.

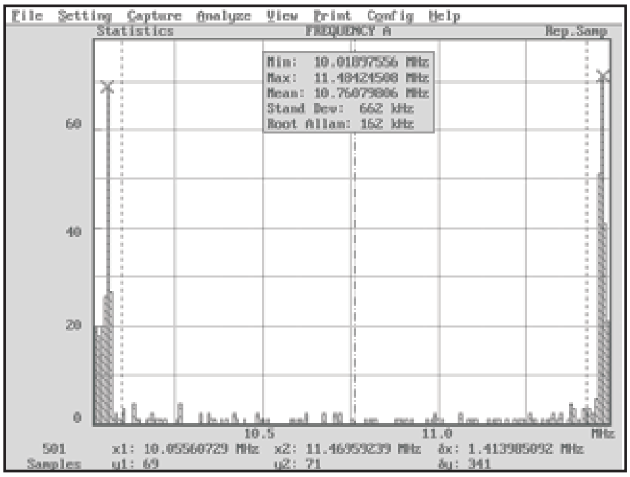


Figure 3 *The distribution histogram of the frequency vs time samples quantifies carrier frequency - the mean value - and frequency deviation - (max-min)/2*

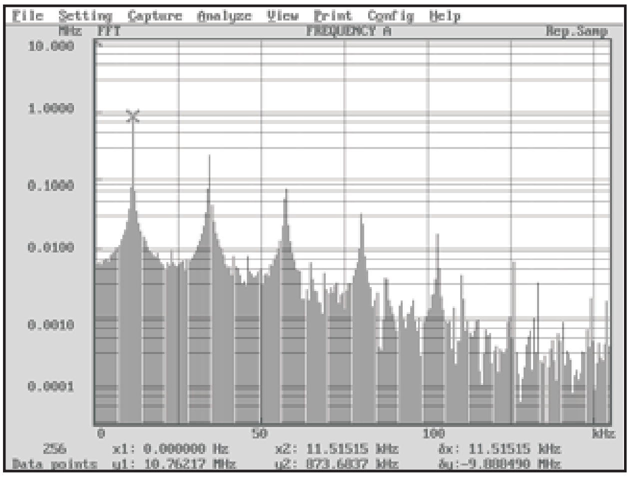


Figure 4 *FFT-processsing of the frequency vs time data in figure 2 reveals a modulation frequency of 11.5 kHz (see cursor2, x2=11.5... MHz)*

pendulum