Undersampling extends utility of digital scopes

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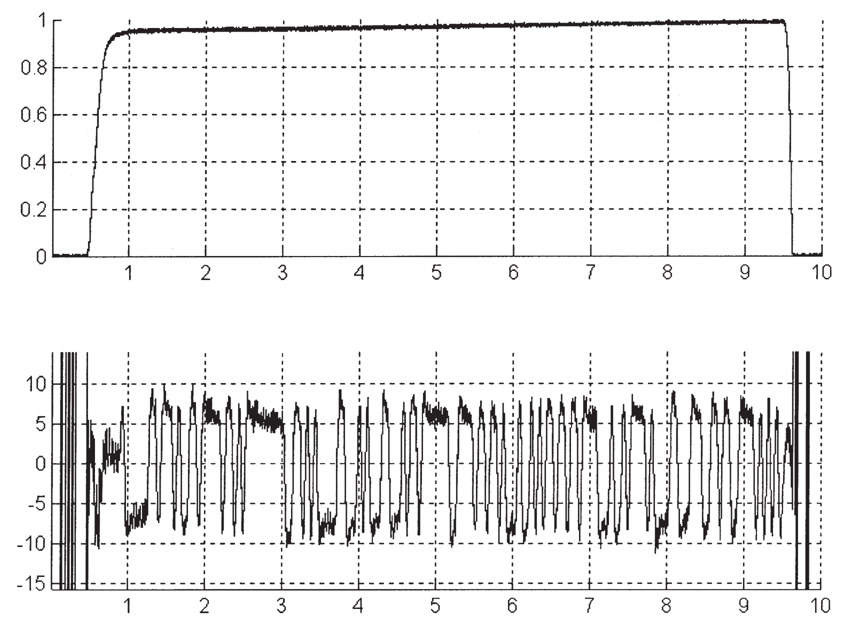
By undersampling the input signal, you can use a digital oscilloscope to digitize and display or collect signal data of even RF and IF signals. To sample a signal without aliasing, you must use a sampling rate that satisfies the relationship

$$f_M = f_S/2$$

where f_M is the maximum allowable signal frequency and f_S is the sampling rate. If you want the sampled signal data to directly form a high-quality visual representation of the signal waveform, a considerably higher sampling rate is necessary. A practical implication of this equation for high-frequency signals is that you can acquire sequences of signal data for only short periods before the available memory is filled.

However, many high-frequency signals, such as RF and IF signals in communications systems, are bandpass signals whose bandwidths are very small relative to the center frequencies. Consequently, you can intentionally undersample these signals so that their spectral components alias to lower frequencies. To ensure that the spectral

FIGURE 1



An undersampling technique helps capture the envelope (a) and instantaneous frequency (b) of a single hop from a typical frequency-hopping radio using FSK modulation.

$$f_L \geq mf_S,$$

components of the signal do not fold over on themselves or become reversed, you must choose the sampling rate, f_S,

$$f_U < (2m+1)f_S/2,$$

such that simultaneous solutions exist for
and
where $m=f_L/f_S$ (an integer) and f_L and f_U are the respective upper and lower bounds for the bandwidth that the signal of interest occupies. The undersampled signal differs from the original signal by a downward shift in frequency of mf_S. In carrying out this concept, you need to disable analog lowpass filters at the oscilloscope input or ensure that the filters have a cutoff frequency high enough to preserve the signal information.

You can apply this concept to practical applications, such as the digitization, storage, and analysis of the RF-signal output from a VHF radio that employs frequency-hopping techniques. In this application, the radio was programmed so that the signal would hop to a carrier frequency of 71.9 MHz at frequent intervals. A bandpass filter centered about 70 MHz with a bandwidth of 5.6 MHz attenuated and bandlimited the transmitted signal. A LeCroy (www.lecroy.com) 9354 digital sampling oscilloscope, operating at a sampling rate of 10 MHz, generates records of 100k data samples. The choice of carrier frequency and sampling rate results in the aliasing of the RF signal to 1.9 MHz. Note that the use of a sampling rate of 200 or 250 MHz would not allow the storage of sufficient data for a complete hop.

You can then use Mathworks' (www.mathworks.com) Matlab to implement signal-processing algorithms for amplitude and frequency demodulation of data sequences associated with individual hops. **Figure 1** shows the time-domain behavior of the amplitude and instantaneous frequency measured for a representative hop signal. You can discern the FSK modulation in the switching of the instantaneous frequency between two discrete frequencies. (DI #2190) EDN

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