Signal Differentiation

The task of finding a feeble 0.1 to 1 Hz photoelectron pulse amid tens and hundreds of thousands of stellar light created photoelectrons is a a multi-step process. As has been discussed in other sections, the initial rendering is done by discarding most of the random Poisson pulses. This leaves us with near zero to as many as 20 pulses per second of residual noise. Potentially buried in this is our hoped for detectable laser signal. Clearly if the residual noise pulses are well below 1 Hz, the signal can easily be ferreted out. But how does one distinguish signal from noise pulses a hundred or more times more frequent?

The answer to this was found more or less serendipitously. Early tests with a computer-based audio spectrum fast Fourier Transform (fft) analyzer showed that periodic pulsed signals buried in noise exhibited the fundamental frequency peak and all of the harmonics at approximately equal levels. Thus, even though there were scattered noise peaks equal to or even greater in amplitude, the periodic test pulses could easily be detected by looking for the harmonics. And, concomitant with having all of the harmonics, the harmonics are spaced equally according to the fundamental. In other words, if one were looking at the spectrum in the 10 to 15 Hz range, a one Hz signal would be seen at 10, 11, 12, 13, 14 and 15 Hz. Given my inexperience with fft analysis, this seemed in error or was perhaps an artifact of a particular software package.

With a bit of digging, I found several articles relating to pulse signal analysis with fft. The most helpful was a chapter in *The Scientist and Engineer's Guide to Digital Signal Processing,* (Stephen W. Smith, 1999), where he relates the pulse width to the characteristics of the fft frequency domain. For example, a square wave exhibits the 1st, 3rd and 5th harmonics, but a pulse at about 25% duty cycle exhibits the 1st, 2nd, 3rd, 4th, 5th, and so on, but with varying and diminished amplitudes. Wanting test data with the particular fft analyzer, I obtained a pulse generator and did the tests. The result was that as the pulse width was diminished to a small duty cycle, the fft frequency domain harmonics all rose to about equal amplitudes. So, the effect noted with optical test pulses from the led pulser was real, effective and very advantageous.

It then became apparent that the system could tolerate a greater background count while still providing clear signal to background differentiation. The next step, therefore, was to add a relay in the photometer head to permit remote (keyboard) switching between tracking Poisson n=3 and n=2. As it turned out, the background pmt total pulse count for magnitude 8 (~20k counts/sec) and greater stars is low enough to permit using n=2 and resulting in a substantial increase in sensitivity to signals where pulses may be missing due to pmt quantum efficiency, atmospheric extinction, etc.