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Photometer Pulse Group and Pulse Coincidence Calibration Methods

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There are at least two calibrations of the photometer that have always been a little thorny. The first, of course, is the setting of the 1st discriminator level. That setting is a compromise between sensitivity and noise and is dealt with in the website section on photomultiplier information. Of concern here are the settings of the downstream coincidence and group pulse discriminators.

In the discussion on "Is Amateur OS Viable", it was shown that for small telescopes it is important to minimize sensitivity robbing compromises. The big guys with telescopes larger than 1 meter, can discard a few photons in favor of eliminating false positive detections and they typically operate at n=4 or greater as regards the Poisson statistics. We on the other hand have to deal with this issue more carefully, operate with higher sensitivity at n=2 and 3, and handle more frequent false positives in another way. (See the section on signal processing regarding spectrum analysis of signals).

The adjustments discussed here have been of concern for several years. A means of photometer calibration and testing was needed that left little doubt as to the system sensitivity. After all, we spend countless hours observing and one hates to think that your main toy may be poorly set up and those hours could not bear fruit even if the fruit was there for the picking. An LED test light source was developed several years ago, but recent improvements have cleared up a few nagging concerns. The test source circuit and characteristics are covered in the section “An LED Pulser”. The pulser has two LED sources: one for pulsed signals that simulate a laser signal and the other for simulating a range of stellar backgrounds. The pulsed signal’s width can be adjusted from ~1ns to 50 ns and with repetition rates from 0.05 Hz up to 3 Hz. It isn’t necessary to simulate pulsed signals at rates greater than 3 Hz since they are very easily detected. The simulated stellar background can be set from 0 counts per second to 1 million counts per second, thus covering the range from the dimmest star (m_v 14.5) to the brightest star that can be observed here without overloading the photometer (m_v 5).

Pulse Coincidence Detection. Let's begin with the pulse coincidence mode setup. For this we disable the LED test pulses (rotary switch position 0). Since the photomultiplier photoelectron pulses after the 1st discriminator are about 5 ns wide we should allow that coincidence must occur within 5 ns. Referring to the chart on the next page, if we are setting up for a 3 photon coincident event (n=3) then random coincidence should be detected at an average rate of 1 pulse per second when the background total count (LED output) is raised to about 750kHz.

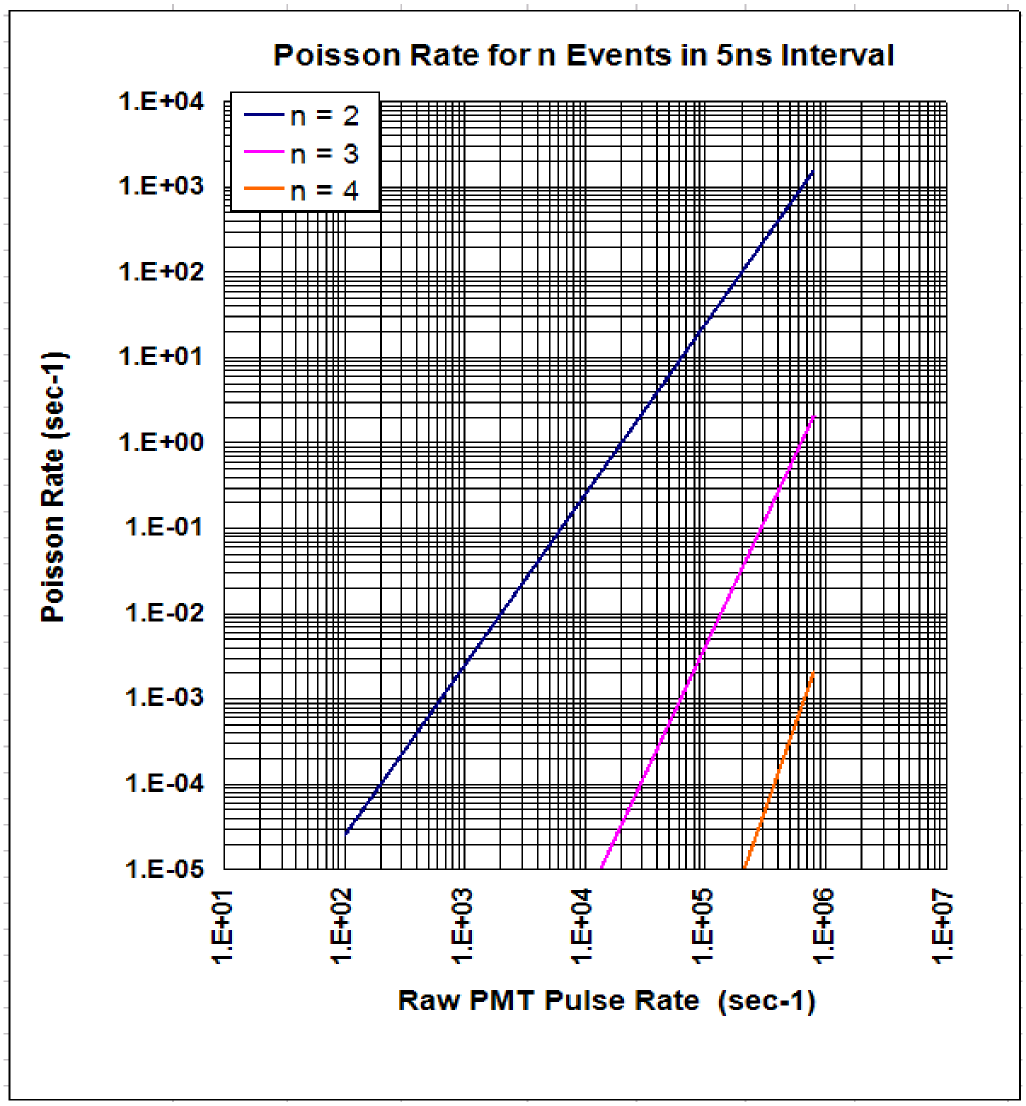


Figure 1.

In the same way, one can set the n=2 coincidence threshold such that 1 pulse per second is detected at 20 kHz total count rate. One can of course choose to operate at n=2.5 or 3.5 or whatever to suit personal preferences regarding the compromise between sensitivity and false positives. The best situation is to automatically adjust this threshold over the range of background counts to maintain the best sensitivity with a reasonably low hit rate i.e., ≤1 hit per second.

Pulse Group Detection. For this discussion, assume we are setting the system up to detect anomalous groups of pulses 25ns in total width and without significant coincidence to muddy the outcome. Thus, the graph below may be used.

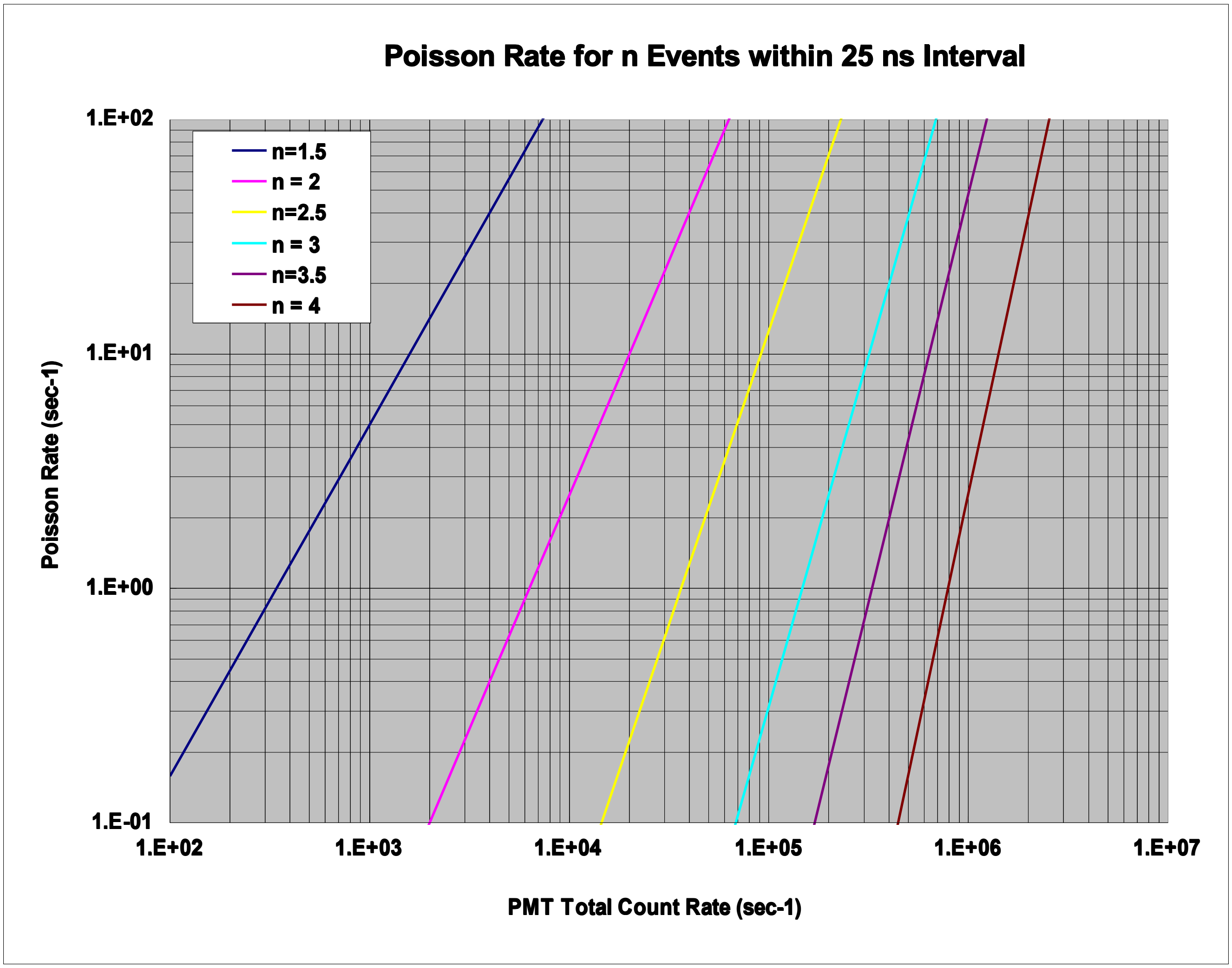
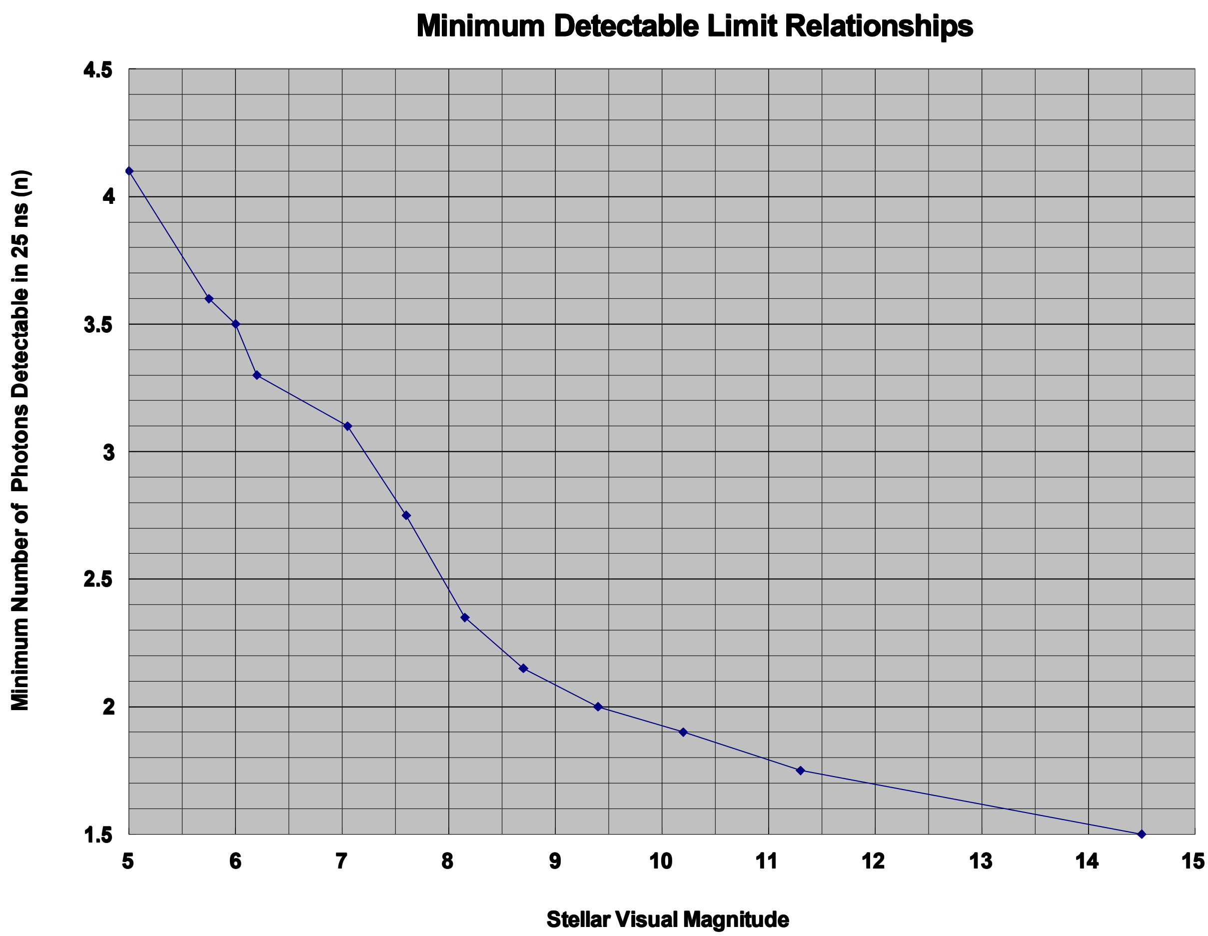


Figure 2.

The pulsed LED drive amplitude was set well below that which would produce coincident pulses at a significant rate i.e., <.001 hits/second.

Next, using the fft, the 2nd discriminator threshold was set to clearly achieve pulsed signal detections near the detectable limit. This was done stepwise over range of background levels consistent with the observable stellar magnitudes. At the lower rate of pulse periodicity, the hit rate is quite low i.e. 0.5 hits per second. Thus, for accuracy, the number of hits was automatically averaged over a 3 minute period. That averaging period was used for all of the data and thus required many hours of attendance.

Figure 3 represents the results of the calibration tests. Each point on the curve corresponds to a 2nd discriminator threshold compromise setting for detecting signal repetition rates greater than 0.05 pulses per second. In practice, those settings are automatically made as each new star is acquired.



The photometer calibration procedure was not obvious and has evolved over time to the current technique. Without a proper pulse/background simulator, these results would not have been possible. Although achieving this has been time consuming, it is now a simple matter to routinely test the system's performance.