IMPROVED LASER RANGING ACCURACY THROUGH DYNAMIC THRESHOLD COMPENSATION

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Laser satellite tracking systems are now being used in support of geodetic and Earth physics programs. The value of the laser tracking system in these programs is dependent on the range noise and the range bias over widely varying conditions for typical satellite passes. During the recently completed preliminary polar motion experiment (an experiment in which two laser ranging systems on a north-south line simultaneously tracked a satellite to determine motion of the pole), new techniques for improving both the range noise and range bias were demonstrated. These techniques typically improved the GSFC laser ranging systems from the former 1.5-m accuracy level to the 20- or 30-cm accuracy level.

The range accuracy of a laser satellite ranging system, separate from that introduced by time jitter and instability in electronic components (presumably small), is dependent on the transmitted pulse duration and the resulting shift in the time of triggering the start and stop of the time interval counter, caused by variations in both transmitted and received signal levels, when a fixed trigger threshold setting is used. This effect for three different received signal levels is illustrated in Figure 1, where the time difference relative to the center of a typical 20 ns transmitted pulse duration is shown. The fixed threshold setting determined by the horizontal line intersects the three pulses at 4, 8, and 14 ns relative to the center of the pulses. However, if the amplitude of the received pulse is the only varying parameter, it can be shown that by adjusting the threshold to a constant value of the peak amplitude, i.e., 50 percent, there is only a constant time offset relative to the center of the pulse.

Dynamic adjustment of the detection threshold is accomplished (Figure 1) by measuring the peak amplitude of the received pulse, recording this value, and then using it to set the threshold level of the threshold detector and trigger generator. The original received pulse, after a known delay, is then detected at the required level, and a trigger pulse is generated to stop the range time interval unit. The dynamic electronic threshold circuitry is capable of measuring pulses having varying amplitude, but fixed shape, with a precision better than 1 ns over a wide dynamic range.

The need for threshold compensation is shown in Figure 2, which illustrates the variation in signal level throughout a typical satellite pass. The measured signal level in photoelectrons varies by more than 100 through the pass with a predominance of high levels at the closest range as expected. The wide variation in signal level from point to point is due to atmospheric perturbations, inhomogeneous beam distribution, corner reflector interference effects, and tracking error, whereas the systematic variation from low to high to low signal level is due to range changes, increased atmospheric path length, and changes in the optical cross section of the satellite with elevation angle.

The corrections to the measured ranges (based on these received signal levels relative to a fixed correction that would have been applied if pulse height information was not available) are also shown in Figure 2. The overall correction span exceeds 4 m, which is far in excess of the observed rms for this pass. Furthermore, visual inspection of the corrections implies that any orbit determined by these corrections would be biased from the true orbit.

Figure 3 shows the improvement that pulse height information and electronic threshold adjustment make for short arc orbital fits. The laser ranges for a satellite pass are used to determine a short arc orbit, and then the measured ranges are compared to the computed orbit. The range residuals are plotted as a function of time throughout the pass. The upper plot shows a noise level of 1.4 m, typical for a constant correction, while a noise level of 24 cm is obtained when the pulse height correction techniques are employed. More important than the reduction of noise level, however, is the reduction in the bias implied in Figure 2.

Noise level and range bias in laser ranging systems can best be reduced by a reduction in transmitted pulse duration below the required precision; however, it has been demonstrated that even existing long pulse systems (20- to 40-ns duration) can be improved to the 20- to 30-cm level of precision without major or expensive changes to the system.

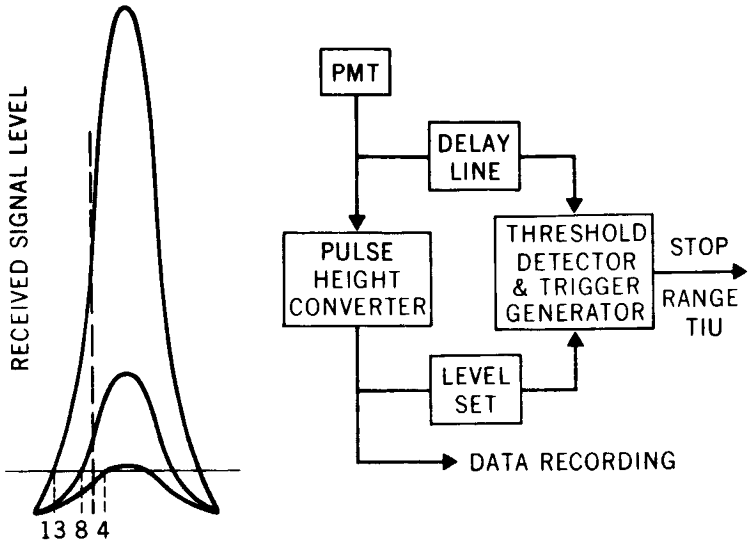

Figure 1–Dynamic threshold compensation.

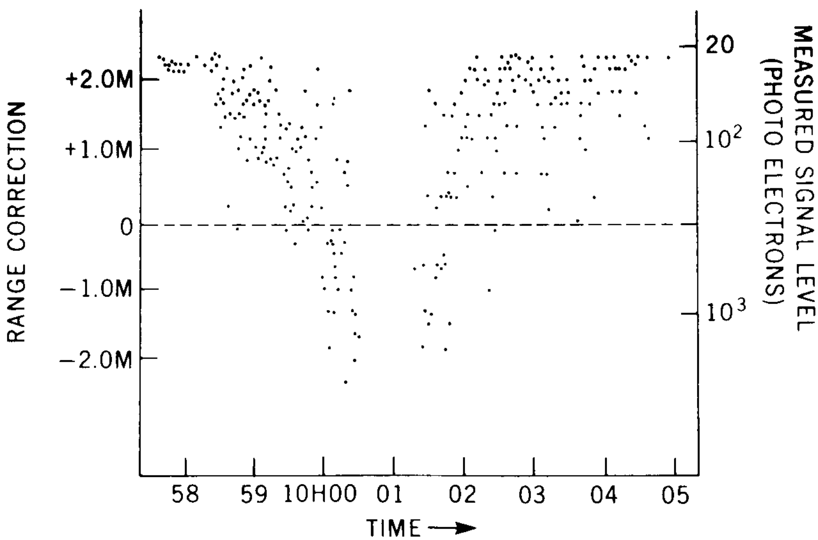

Figure 2–Range correction based on received signal level.

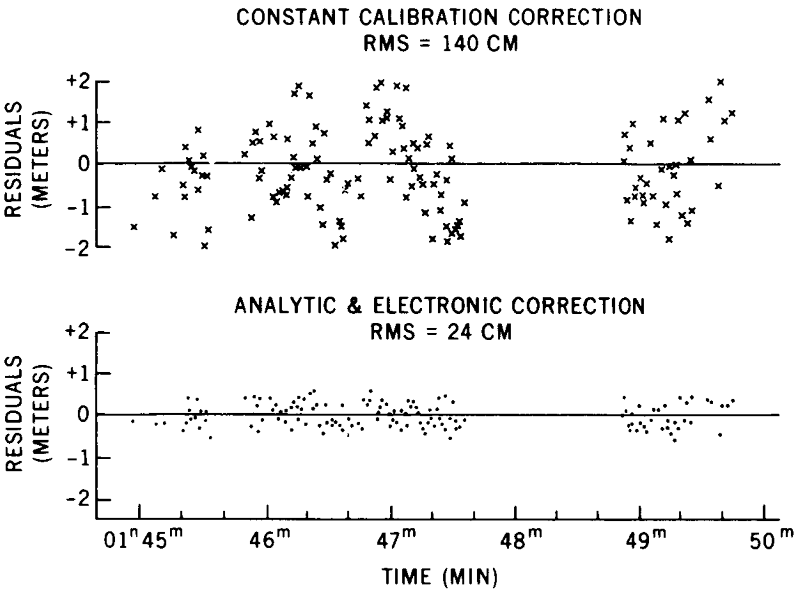

Figure 3—Laser range residuals.