NASA SGSLR Approach to Range Gate and Fire Command Control

C. Clarke[1], J. McGarry[2], E. Hoffman[2], D. Patterson[1], M.Heinick[1]

[1] KBRwyle Technology Solutions LLC, Lanham, MD, USA [2] NASA Goddard Spaceflight Center, Greenbelt, MD USA

Abstract

The Space Geodesy Satellite Laser Ranging (SGSLR) system utilizes an in-house built Range Control Electronic chassis (RCE) to provide precision gating for the Receiver Subsystem, provide a variable frequency fire command signal for the Laser Subsystem, and blank the detector around the laser fires. This poster will provide a description of the hardware along with its interface and interaction with software. The SGSLR system uses common optics for both the transmit and receive paths of the system. To protect the detector from the backscatter of a laser fire when the fire occurs during a receiver gate, the SGSLR system employs both hardware and software solutions so that fires never occur in the range gate. This also maximizes the potential returns as well as protecting the system. These techniques will be discussed in this poster.

Introduction

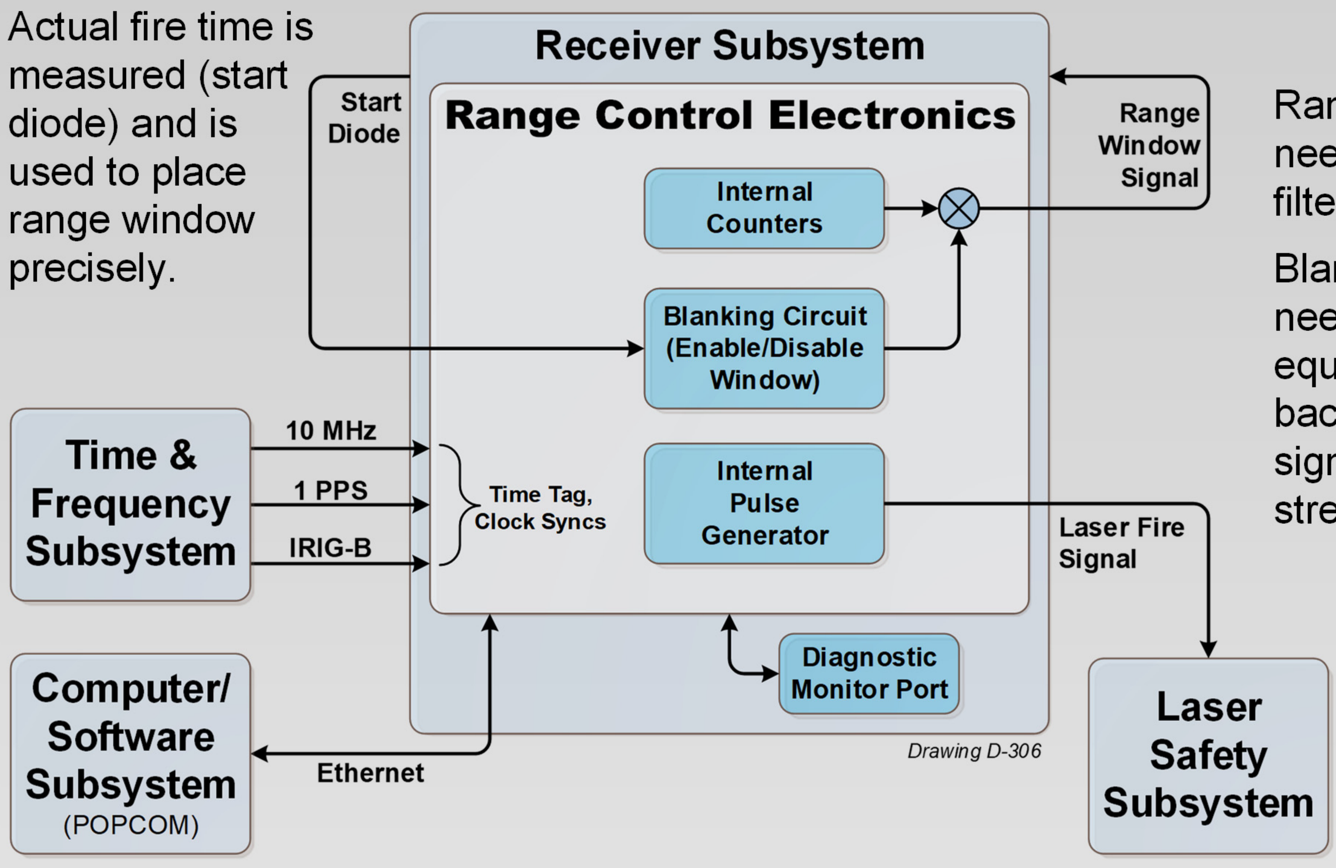
The Range Control Electronics has two main functions:

Generate a gate that "windows" a satellite or calibration (ground/internal) return for the detector in the Receiver System. The window's primary function is to is provide temporal filtering to eliminate noise caused by scattered atmospheric light and stray light in the optical path.

Generate a "laser fire" command signal. The fire command should not occur at the same time as the window. This is to (1) prevent damage to the detector from laser backscatter, and (2) to maximize the satellite return rate. The RCE provides blanking of the detector during laser transmission, so no returns will be occur around the laser fire. The Computer and Software Subsystem adjusts the commanded pulse repetition interval (PRI) so that the fire will not occur in the range window (range gate).

Basic Flow Diagram

Actual fire time is measured (start diode) and is used to place range window precisely.



Range window is needed for temporal filtering of noise.

Blanking of receiver is needed to protect the equipment from laser backscatter and reduce signal noise in the data stream.

Laser fire frequency varied to avoid firing while range window is open.

RCE Build

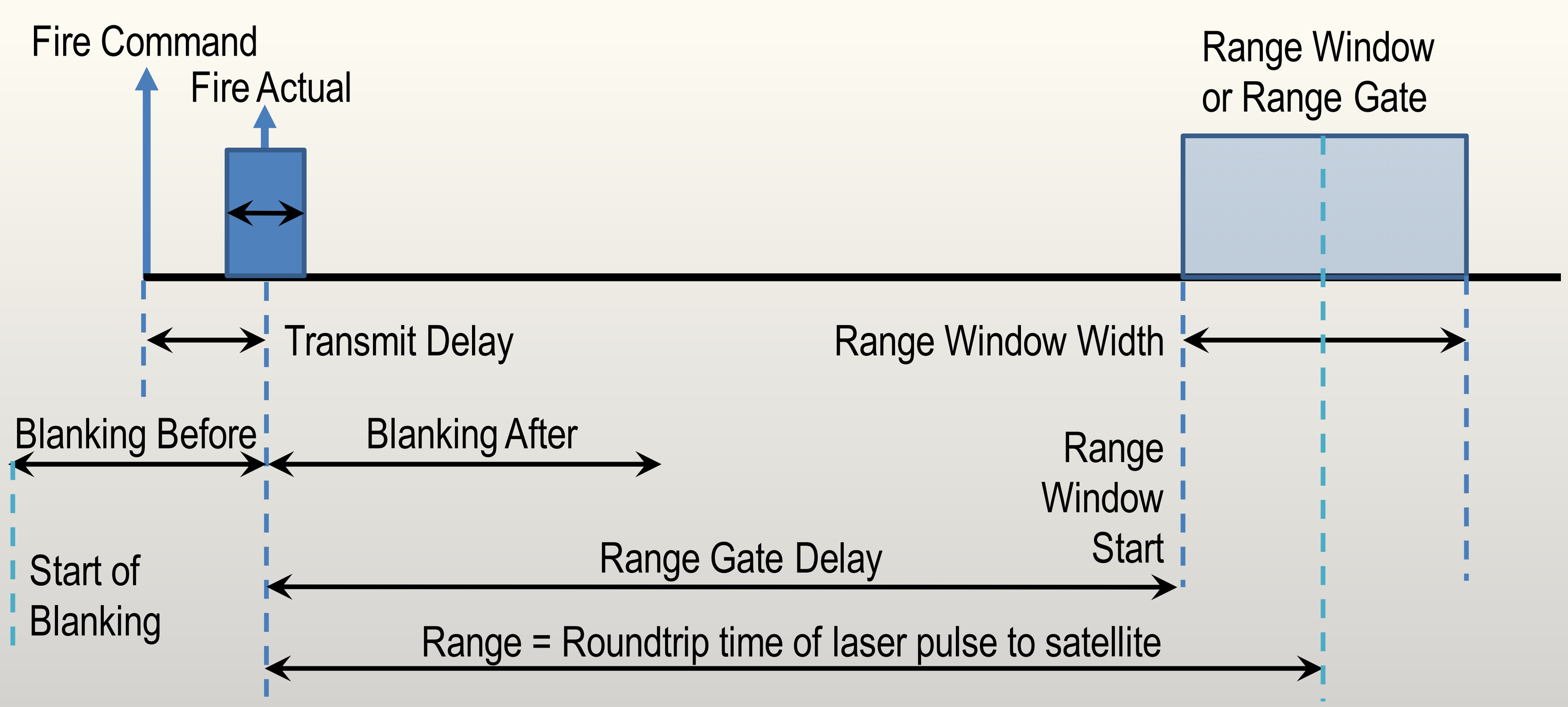
Because there was no commercial product that would perform all functions required for SGSLR, the RCE has been designed/ developed as a NASA in-house build. The build has both COTS components and NASA proprietary components. The proprietary components include signal shaping, interface PCB VDHL-based digital design, and processor software (I/O control circuits).

Software Interface

The RCE receives data bundles from the Computer and Software Subsystem at 20 Hz. Given that SGSLR's nominal fire rate is 2000 Hz, these bundles will contain fire and gating information for approximately 100 fires. The bundles contain the time of the first fire command, the pulse repetition interval (PRI), and the start and width of the range gate for each fire. The bundles are received two 20 Hz intervals in advance. The RCE uses these bundles along with transmit delay information from the receiver in order to generate the gates and blanking times.

Start of Range Window = Fire Command + Transmit delay + Range Gate Delay
End of Range Window = Start of Range Window + Range Window Width

Start of Blanking = Fire Command + Transmit Delay – Blanking Before
End of Blanking = Start of Blanking + Blanking Before + Blanking After



Drawing shows RCE detector blanking and setting of range window.

Software Determination of PRI

The Computer and Software Subsystem utilizes a technique that varies the PRI so that fire events will not occur in blanking region. This technique protects the receiver and optimizes the number of potential returns. The technique uses a nominal PRI and an alternate PRI. The alternate PRI is chosen based upon (1) the size of the blanking region and (2) the values of the round-trip ranges in the selected region. The nominal PRI is 2000 Hz, the alternate PRI is chosen so that switching between the nominal and alternate PRI values will allow the system to keep all the fires out of the detector blanking region. The following equation can be used to determine the alternate PRI for a given size of the blanking region and a given set of round-trip time ranges. (Titterton et al., "System/ Usage Impact of Operating the SLR2000 at 2 kHz", 11th ILRS Workshop, Deggendorf, Germany, 1998)

$$\frac{T_B}{k_{min}} \le \delta T \le \frac{T_0 - T_B}{k_{max}}$$ where,

T_0 = Nominal PRI
T_1 = Alternate PRI
T_B = Total blanking time
k = Number of pulses in flight
δT = Delta from nominal PRI = $(T_1 - T_0)$

The SGSLR system's current plan is to use a total blanking time (T_B) of 60 microseconds and a nominal PRI (T_0) of 500 microseconds (2000 Hz). SGSLR grouped satellites by similar altitudes and determined an alternate PRI for each satellite group that was valid for the equation above when the satellites may be tracked to ten degrees elevation. The PRI was determined by using the minimum round-trip range (range at zenith angle) and maximum round-trip range (largest range at 10 degrees elevation) for each group. k_{max} was determined by dividing the maximum round-trip by the nominal PRI. k_{min} for a potential alternate PRI was determine by dividing the minimum round-trip range by the potential alternate PRI value. If delta from the nominal PRI satisfied the equation above, the PRI was used for that satellite group. If it did not, the alternate PRI was adjusted until it satisfied the equation. A PRI value for each satellite group was determined and is listed in the chart below. The PRI values were chosen so that each of the satellite groups overlapped a small amount.

Satellite Group	Ranges (km)	PRI value (μs)
GEO	30000 to 50000	500.5
GNSS+	10000 to 30000	501
LAGEOS	3900 to 15000	502
MID	1200 to 4000	504
LEO	450 to 1300	510
GOCE	225 to 500	520
LEOx	150 to 300	530

Example Applying PRI

The SGSLR software generates fire and range window times in 20 Hz bundles. When determining if the PRI should be changed, the algorithm "looks ahead" two bundles (0.1 seconds) to account for any prediction errors or other anomalies. The SGSLR is currently planning to use a blanking region that is 10 microseconds before and 50 microseconds after the estimated fire time. If the "look ahead" range window coincides with either of these blanking regions, the PRI is changed.1) below determines "look ahead" range window is before blanking regions 2) determines if it is the after region.

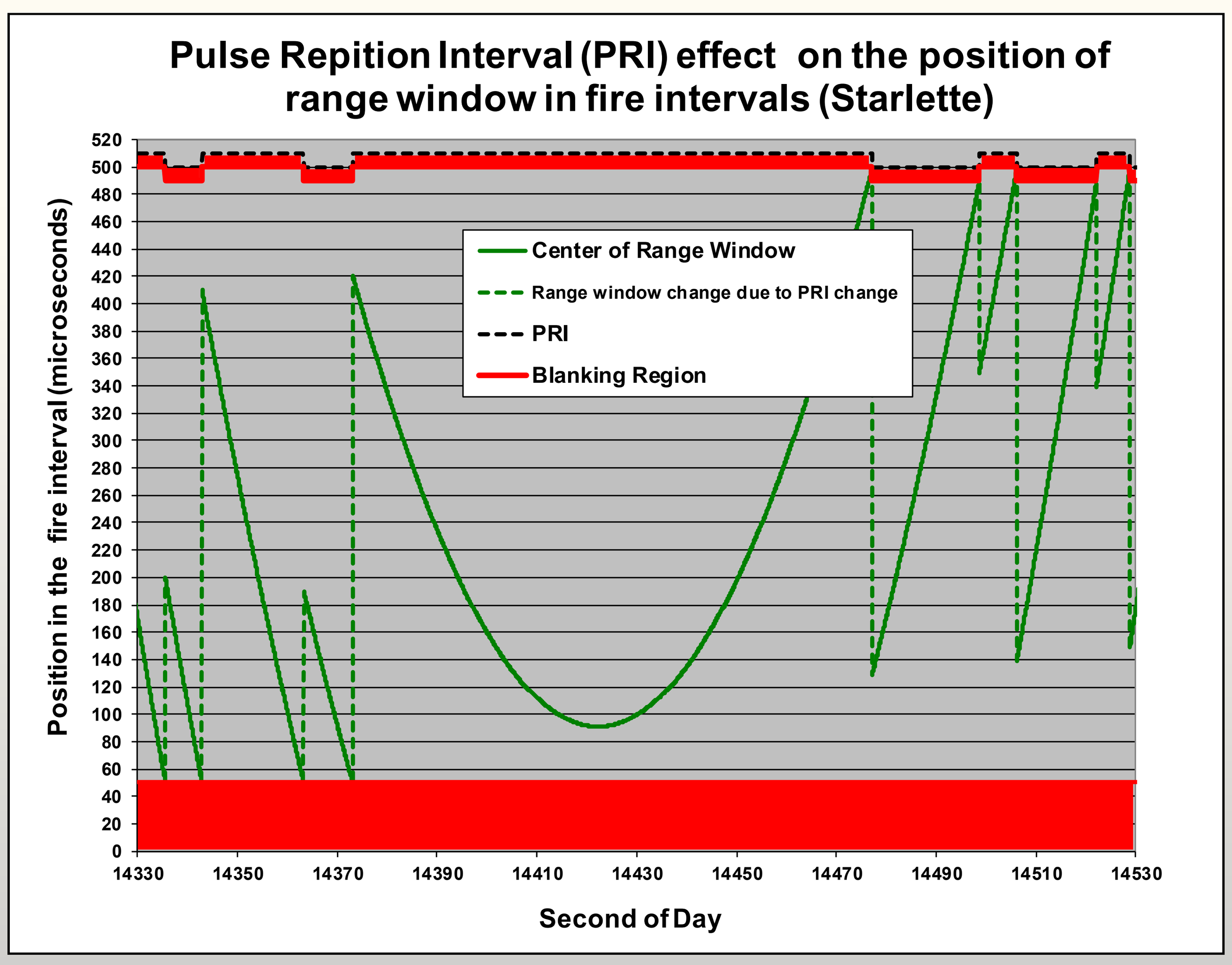
1) $(T_S + 0.1*V_S + 0.5*T_{RG}) \bmod T_{PRI} > T_{PRI} - T_{BB}$

or

2) $(T_S + 0.1*V_S - 0.5*T_{RG}) \bmod T_{PRI} < T_{BA}$

T_S = Predicted time-of-flight of satellite
V_S = Predicted range rate of satellite
T_{RG} = Range gate width
T_{BB} = Before blanking time
T_{BA} = After blanking time
T_{PRI} = Current PRI

The plot below displays a simulated example of where the range window falls in the fire interval during a Starlette pass segment near PCA. The plot displays how changing the PRI keeps the range window from coinciding with the blanking.



Notice as the range window (green line) approaches the blanking region (red), the PRI (blacked dashed line) changes, causing the range window (dashed green line) to move away from the blanking region. The range window never enters the blanking region.

Note: The plot displays the center of the range window. Displaying the start and end of the range window, given a typical range window width (500 ns), would be beyond the granularity of plot.

Reference: Hoffman et al., "SGSLR Range Control Electronics Design and Implementation", 20th ILRS Workshop, Potsdam, Germany, 2016