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NAME John J. Degnan
Sigma Space Corporation, Lanham, MD 20706 USA

EMAIL john.degnan@sigmaspace.com

SESSION Session 3: Accuracy and scheduling

TYPE Presentation

TITLE Challenges to Achieving Millimeter Accuracy Normal Points in Conventional Multiphoton and kHz Single Photon SLR Systems

ABSTRACT

The GGOS challenge to achieve 1 mm accuracy normal points is complicated by many factors, one of which is the way the SLR community traditionally measures pulse time of flight. The Probability Distribution Function (PDF) for the photon time of arrival is given by the convolution of the laser pulse profile, the satellite impulse response, and the detector impulse response. On the transmit/start side, things are simpler due to a stable pulse amplitude and no satellite impulse response to contend with. However, the PDFs for the start and stop pulses are not the same.

In conventional multiphoton lidars, a Constant Fraction Discriminator (CDF) is often used in both the start and stop receiver channels to largely eliminate variable range biases caused by signal strength variations but, due to the different start and stop PDFs, the range measurement is not bias free. Furthermore, the bias varies with different satellite retroreflector geometries, and, for non-spherically symmetric satellites (e.g. GNSS flat panels) , the relevant receive PDF can even take on different shapes during a pass which can in turn introduce time dependent range biases.

In kHz Single Photon SLR systems, the observed signal strength can vary over a wide range due to satellite altitude, elevation angle, atmospheric conditions, etc. Most kHz stations tend to operate with low return rates of 10% or less in order to avoid “first photon” range bias effects. Unfortunately, this greatly increases the time required to generate a 1mm RMS normal point, resulting in much longer orbital arcs associated with each satellite normal point and fewer satellite tracking opportunities overall.

First photon bias effects can be avoided in both conventional and kHz SLR systems by abandoning current threshold based detection and instead recording all of the available start and stop photons in a receiver designed to detect the centroid of the pulses. Although such techniques have been used by radar engineers, SLR implementation would require use of optical detectors capable of detecting and combining all of the individual photon events into a single waveform. MicroChannel Plate Photomultiplier Tubes and Silicon Photomultipliers would qualify because they permit a large number of of near simultaneous photons to be detected, amplified and output to a single anode. Following the radar approach, the observed waveform would be input to an integrator, whose output would be split with one half input to an inverting integrator and then summed with the other half and input to a zero-crossing detector which yields the time centroid of the pulse plus a constant which is determined during

ground calibrations. The input and output centroids would then be used to compute an “unbiased” range. Centroid detection can be easily implemented in most conventional or kHz single photon systems employing single start and stop timing channels, and can even be adapted to SGSLR’s Multifunctional 45 pixel Receiver. Nevertheless, the efficacy of centroid detection in a low signal-to-noise environment needs to be studied.