Linear polarization issues for Laser Ranging to uncoated retro-reflectors [on HEO satellites]

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Introduction

Most of the recently launched GNSS satellites use *uncoated* corner cubes, as opposed to the previously used *coated* cubes. The advantage of the new types is a significantly better response, resulting in more passes, including more daylight tracking, of these HEO satellites.

Because there were some hints that polarization of the laser beam might have some influence on the measured distance for the *uncoated* corner cubes, we setup an experiment to verify this.

The experiment

The 2-kHz DPSS Nd_VAN laser used in Graz emits a linearly polarized beam; the polarization plane orientation on the laser table was determined. The ranging software was enhanced to re-calculate this orientation according to the pointing directions of the telescope, so that the final orientation of the polarization plane – after leaving the transmit telescope - was known & and is visualized during tracking.

On the laser bench, we inserted a λ/2 wave plate in a rotary housing into the laser beam path. The plate orientation is continuously controlled and adjusted by the real time PC; this allows setting the orientation of the linear polarization plane in any desired direction (fig.1).

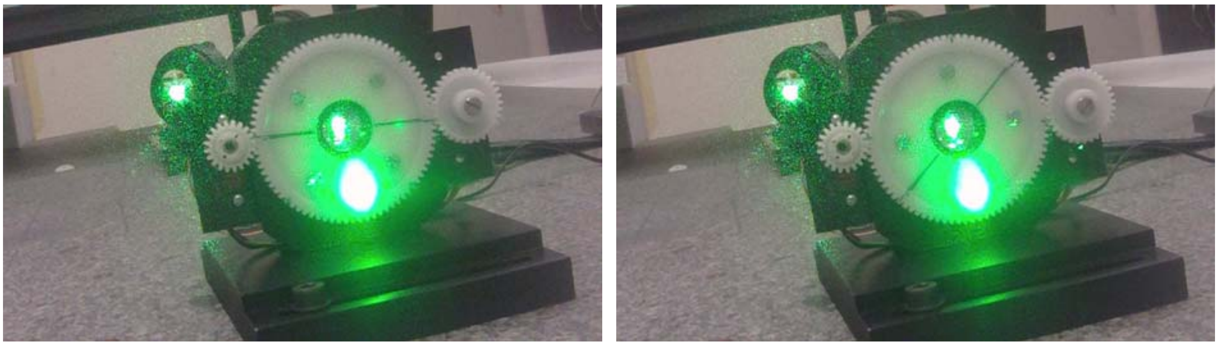

Fig. 1, left: λ72 wave plate at 0°; right: at 45° (this rotates the polarization plane by 90°)

The tests were started by tracking the Chinese Compass-M1 satellite, which carries one of the first retro panels with *uncoated* corner cube retro-reflectors (CCRs). We tracked a night time pass for almost its full length of about 4 hours, collecting about 2 million points. The polarization plane was switched during tracking in 1-minute intervals: 1 Minute with polarization plane ALONG the orbit motion (even minutes), and 1 minute ACROSS (odd minutes). Forming 1-minute Normal Points with the resulting data, a small but clearly visible range difference between the 2 ‘types’ of Normal Points can be seen: Starting from about 1 mm at 32° elevation, it decreases to ZERO at elevations of > 60°. The resolution of these differences is about 0.2 mm, which is the theoretical limit of the Graz SLR system (Fig.2). Tracking a few more passes of Compass-M1, the results could be verified; a first report about this effect was published at the ILRS workshop in Kötzting 2011.

After Kötzting, we extended these tests to other GNSS satellites with both *coated* and *uncoated* CCRs; while there was no evidence of such effects on *coated* CCRs, we could detect some significantly larger differences at ones: The largest difference was > 8 mm, measured on Glonass-115 satellite (fig. 3).

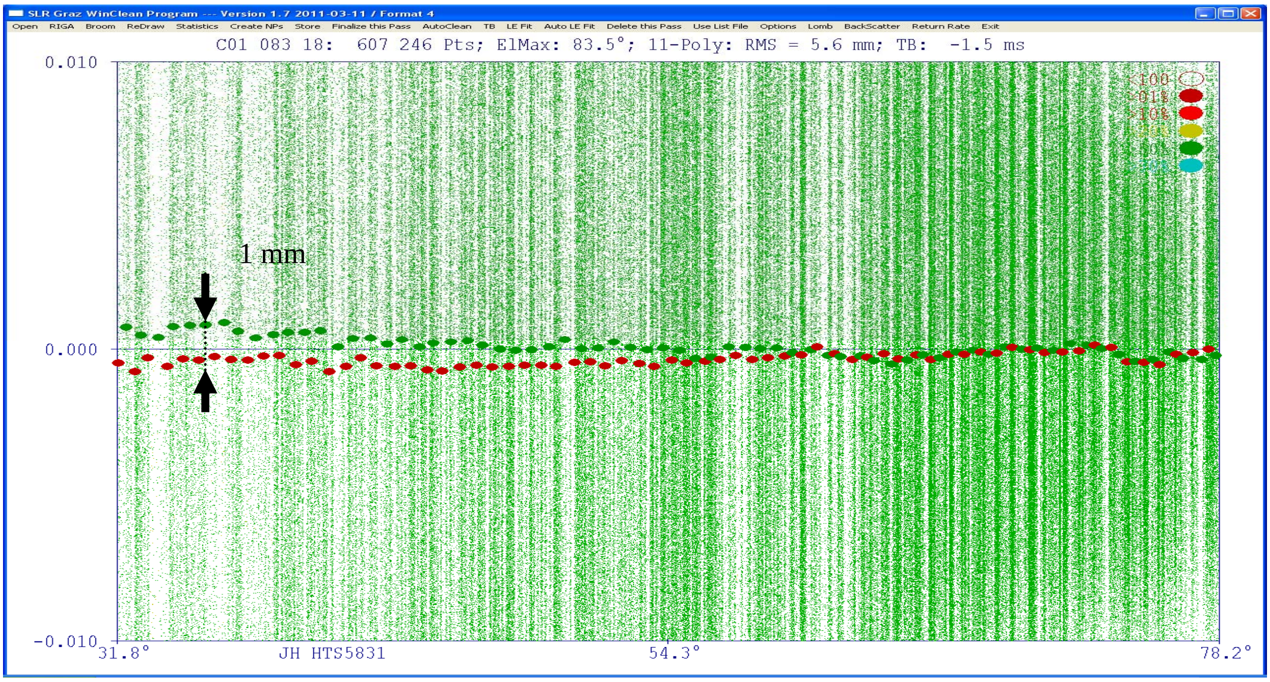

Fig. 2: Compass-M1, day 083/2011: 1-minute NPs; Green NPs: POL plane ACROSS orbit vector; RED NPs: POL plane ALONG orbit vector.

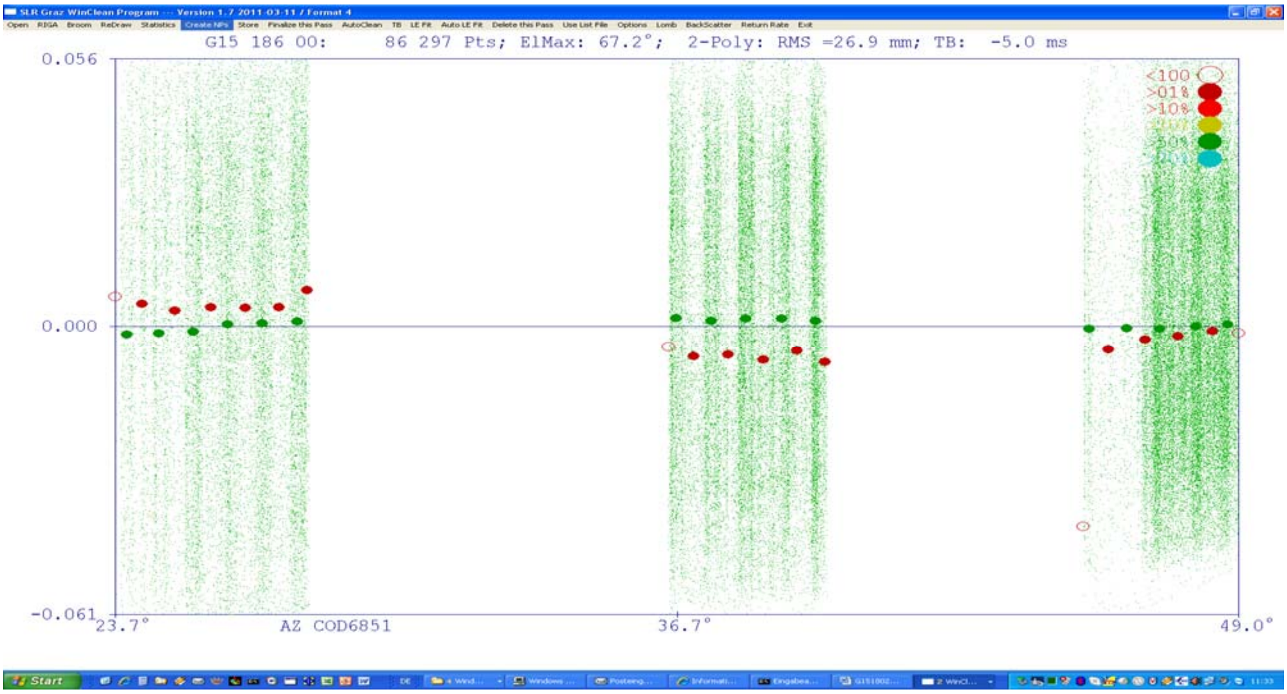

Fig. 3: Glonass 115 / uncoated CCRs: Green & Red NPs (ACROSS / ALONG orbit vector) are changing position; maximum distances: Up to 8.8 mm (middle block)

The results

There were a few systematic results we could identify and confirm:

- The differences were larger at lower elevations, and disappeared at close-to-zenith elevations
- The range differences were larger at Glonass satellites than those on the Compass-M1
- The range differences appeared in BOTH directions: Sometimes the ‘ALONG-Track’ NPs were shorter, sometimes the ‘ACROSS-Track’ (fig. 3).
- The range differences were visible on GNSS satellites with uncoated CCRs (Compass-M1, Glonass-115 / -122 / -123 / -124), but not on those with coated CCRs (e.g. Glonass-125).

The explanation

All GNSS satellites are stabilized; and all of them have flat retro-reflector panels (although in various geometries). The incidence angle of the laser beam is varying with elevation. Furthermore, due to the distance, and due to the low energy per pulse (400 µJ) of our kHz laser, we expect – and we get - only single photon echoes from these satellites.

The mean reflection point for these echoes should be the centre of the panel. However, due to non-perfect manufacturing, the CCRs are not completely identical, and their far field diffraction pattern (FFDP) will vary. For *uncoated* CCRs these FFDPs will also vary with polarization plane orientation. This allows us – by switching the polarization plane – to detect these variations; the mean reflection point will move slightly, in any direction. At near-zenith elevations, there will be no distance differences measureable, due to close-to-normal incidence. The effect will be maximum at low elevations (due to the low incidence angle); it will appear in any direction (because the sum of FFDPs may vary in any direction), and it should be present on coated and uncoated CCRs - but only on uncoated CCRs it is possible to observe the effect directly because the range correction here is polarization dependent (Dave Arnold).

References:

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