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Work at Graz on Satellite Signatures

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Abstract

The size and shape of the satellites retroreflector arrays have a major impact on the distribution and scatter of the return signal; this can be seen clearly when reaching sub-cm ranging accuracies and when using Single-Photon Detectors with single- or multi-photon returns; for other receiver systems (using MCP's) it should be checked also. As a consequence, the necessary center-of-mass correction for some satellites will different, depending on the receiver systems.

While this effect is not yet visible on small satellites or small retro-reflector arrays (like STARLETTE, ERS1), it can be in the order of centimeters on AJISAI or ETALON.

1.0 Introduction

The SLR station Graz uses, since some years, Single Photon Avalanche Diodes (SPAD) to detect return signals from satellites; these diodes can detect single photons - which is used for ranging to ETALON, or, in worse atmospheric conditions, also for lower satellites -, but usually we use multiphoton returns to get maximum return rates; this results in better accuracies when using Normal-Point-Methods, and helps to avoid part of the satellite signatures in the return signal distribution, as described later.

2.0 Ranging tests to the calibration target

Standard calibration to our target (distance about 400 m) gives an RMS of 6 to 7 mm for the routine SLR setup (with HP5370A counter, SPAD at 10 V above break, cooled to -27°C; 2.5σ limits); an example is shown in fig. 1, upper histogram; the distribution shows nice symmetry, with an RMS of 5.8 mm at 2.5σ ; there is no significant change of the mean value when using different sigma criteria, also indicating a proper distribution.

To check influences of the ranging system itself on the distribution of the return signals, different tests with various misadjustments of the involved devices were made; a worst-case example is shown in fig. 1, lower histogram: A similar calibration as before, but with misaligned SPAD, lower voltage above break, no cooling, and non-optimum start puls detection; this results in a non-symmetric distribution, higher RMS, and measurable shift of the mean value for varying sigma criteria.

After verifying the maximum contribution of the system itself, the distribution of returns from different satellites were analyzed.

3. ERS1 and STARLETTE

Due to their small size of the retroreflector arrays, there is no significant satellite signature visible in ERS1 and STARLETTE data; the average RMS is between 8 and 9 mm, close to the values obtained from the calibration target.

The distribution of the data (fig. 2, upper histogram) is more or less symmetric, with small irregularities due to lower number of returns; the 3 mm bin width for all these histograms was chosen in coincidence with the 20 ps resolution of the HP 5370A counter.

4.0 AJISAI

As a contrast to the previous satellites, AJISAI shows quite significant signatures; these are very dependant of the return signal strength (fig. 3).

With strong (multiphoton) return signals, AJISAI shows low RMS (11.8 mm, upper histogram), and only slightly non-symmetric distribution; when reducing the return signal level to mostly single photon-electrons (by switching off the last laser amplifier, and opening divergence; the return signal level is checked in real time by watching the return signal rate and/or the number of semi-train returns on a graphic screen), the RMS increases to 22 mm (lower histogram), while the distribution now follows the shape of the satellite.

Both histograms in fig. 3 are shown with editing criteria of 2.5 σ, which is used for our routine ranging procedures; using other σ values (4 σ, 3 σ, 2 σ), the mean value of the histogram will move - in the worst cases - between 1 and almost 2 cm.

5.0 LAGEOS

As expected from size and shape of LAGEOS, the satellite signature is much less visible than with AJISAI, but is still present (fig. 2); it is the main contribution to the increase of the RMS, from 6 to 7 mm from the target, to 11 to 14 mm from the satellite (again, this is valid for our single-photon detection system, using single photon and/or multi-photon return signals!!), with lower signal levels resulting in higher RMS.

When using different editing criteria again, the non-symmetric distribution causes a shift of the mean value of about 1 to 2 mm, only in extreme cases up to 4 mm.

6.0 ETALON

To complete the satellite's list, we show also the signature coming from ETALON ranging data, this time using a different way of demonstrating the non-symmetric distribution. While fig. 4 shows the residuals of an ETALON-2 pass (demonstrating also the advantage of using the semitrain!), in fig. 5 the residuals are plotted after "folding", polynomial fitting and 2.5σ-editing. Due to the low return signal level from these satellites (most of the returns are single photons: We are ranging with 5 to 10 mJ Semitrain - this is about 2 or 3 mJ for the first pulse! - and 50 cm receiver to the ETALONS, still getting return rates of up to 1000 returns per hour), we see the full satellite's size and shape in the data, with an RMS of 3.5 to 4 cm

7.0 Conclusion

To keep systematic errors due to the influence of the satellite's shape as low as possible, we

- keep calibration and satellite return signals in the same level
- use the same editing criteria (2.5 σ) for calibration and for satellite data;
- try to minimize any contributions of the system itself to non-symmetric distributions.

As far as we know, in all analyzing calculations the satellites are treated as a "flat" reflecting surface, with a fixed center-of-mass correction, which was determined before launch using the detectors, techniques and accuracies available at that time. However, with the improvements in accuracy, we can see now the shape of the satellites in our data, which in turn can influence the values of the center-of-mass corrections; so it seems necessary to determine the center-of-mass correction with respect to different receiver systems, and using different values for the analysis.

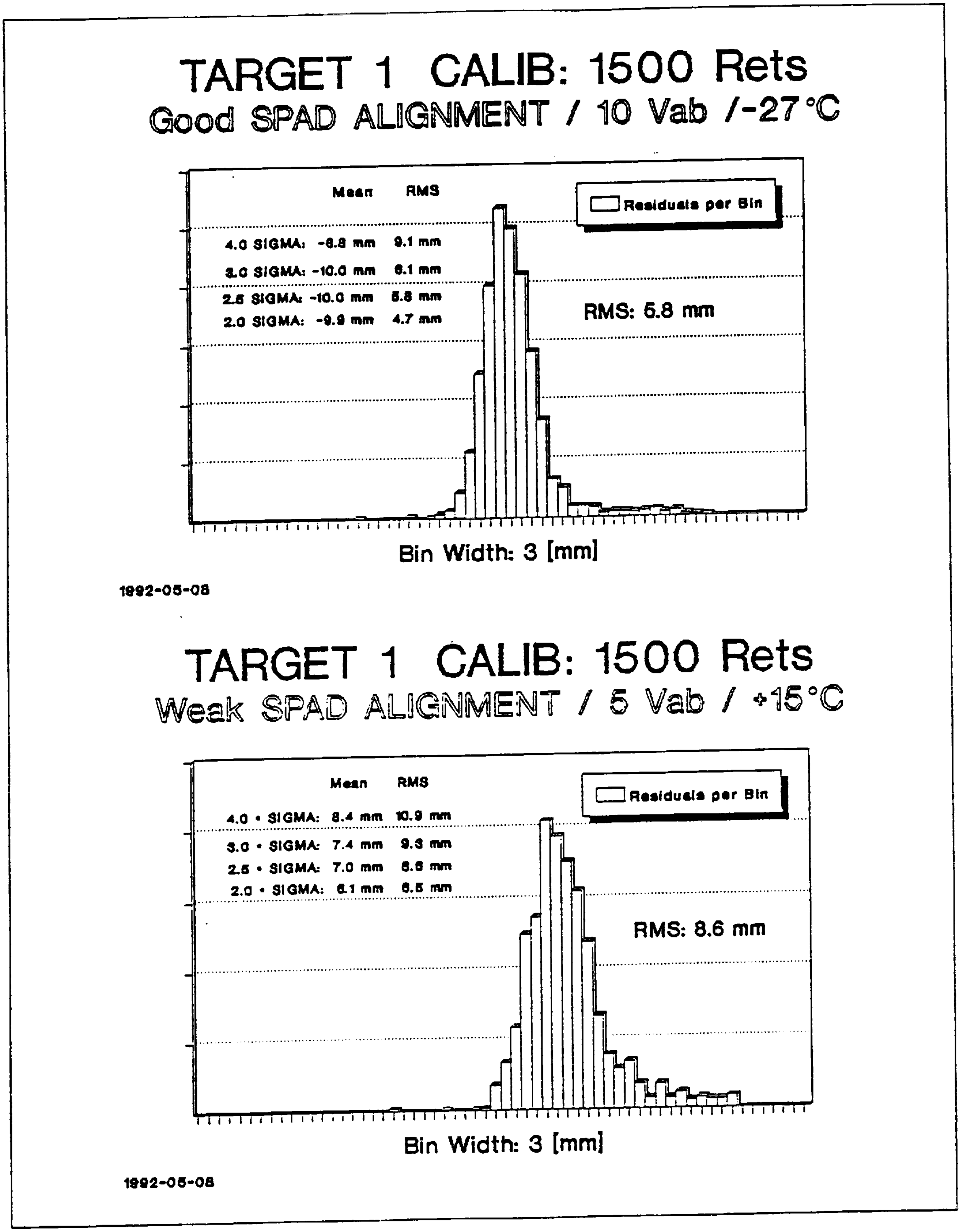

Figure 1: Histograms of calibration ranging to the target

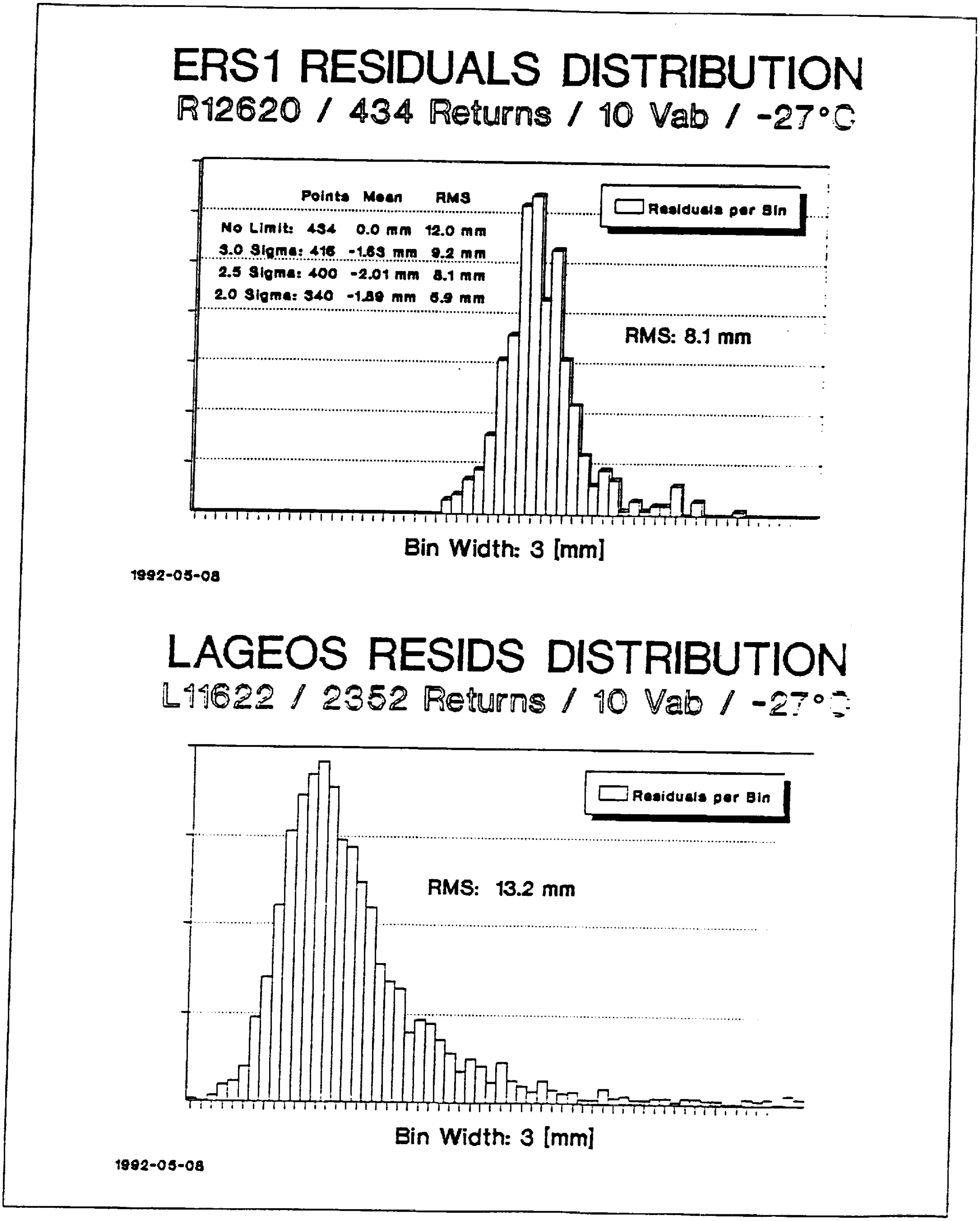

Figure 2: Histograms of ERS1 and LAGEOS returns

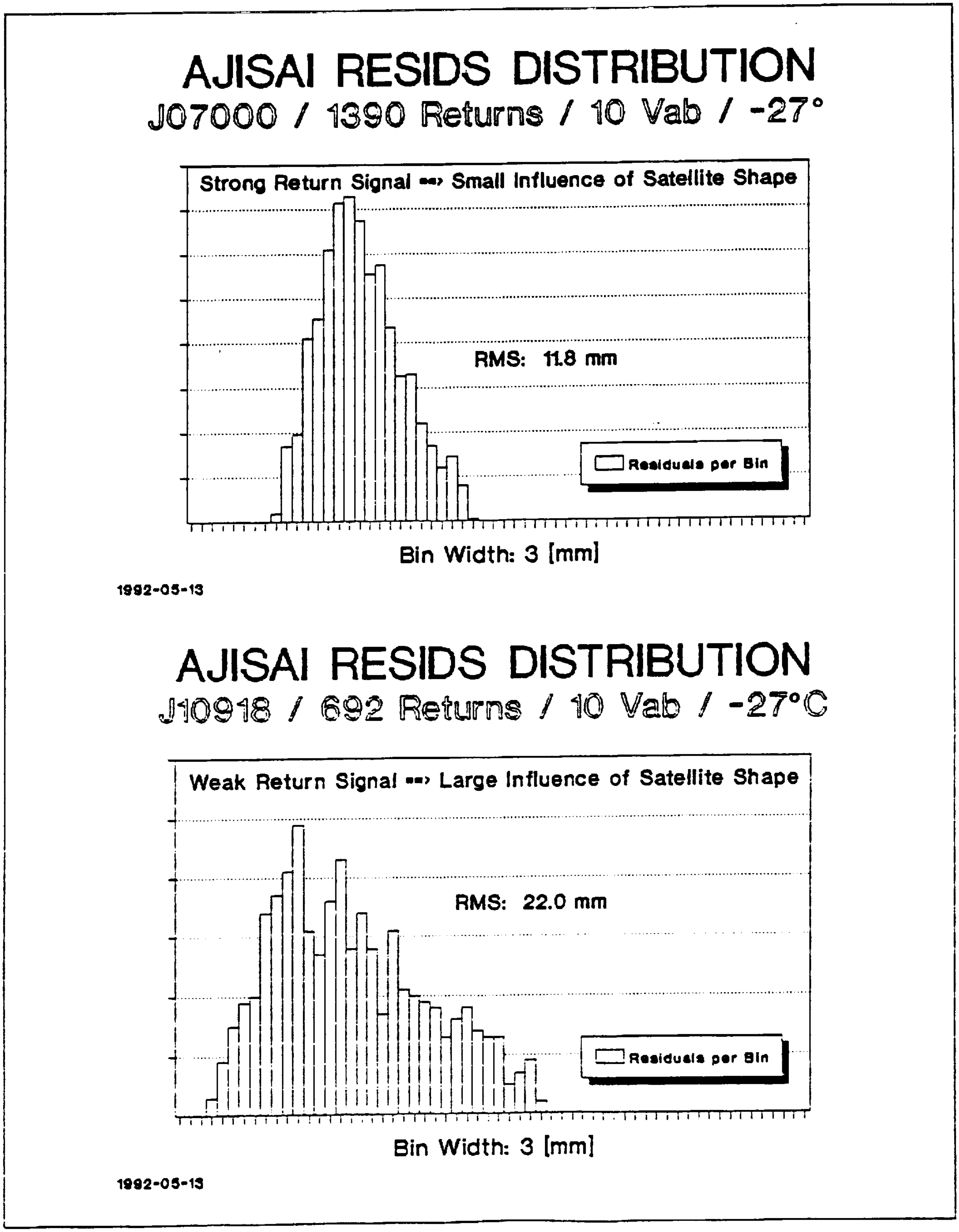

Figure 3: Histograms of AJISAI returns

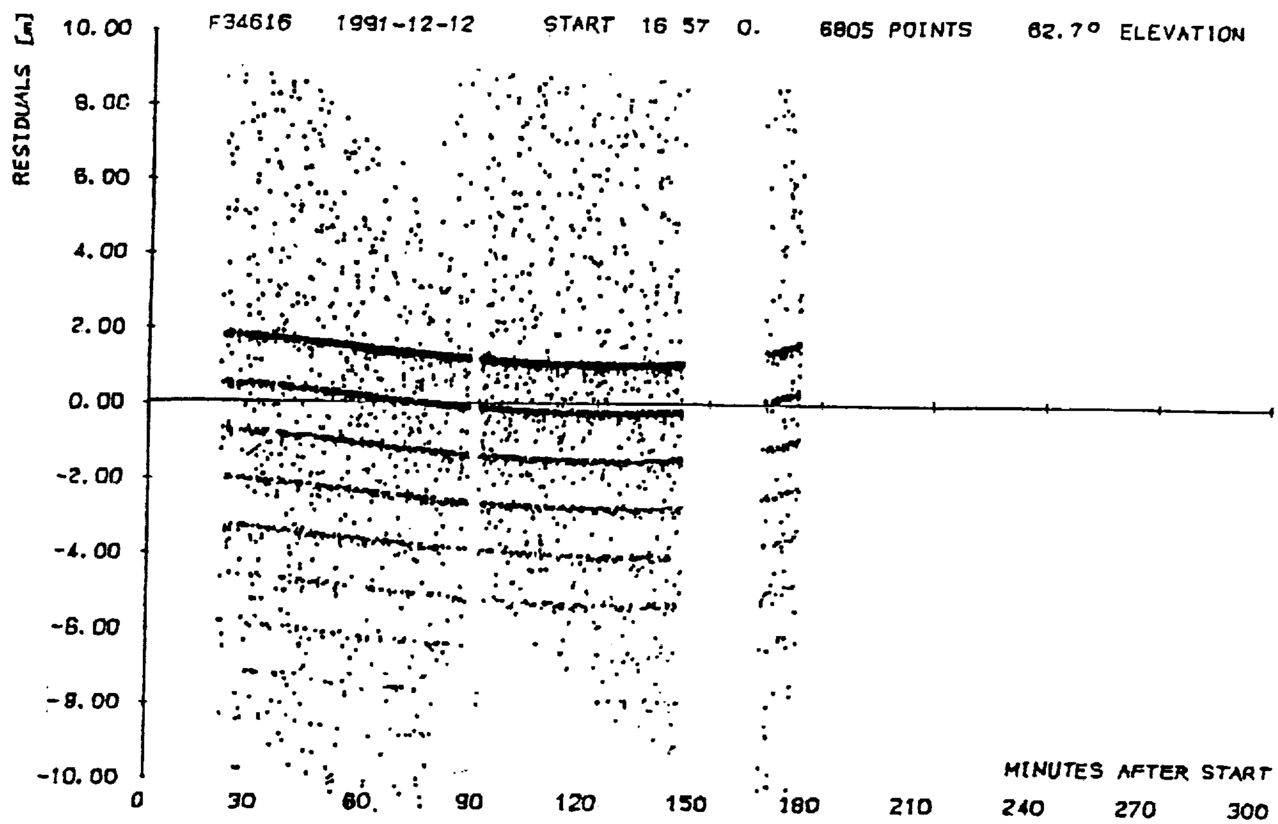

Figure 4: Residuals of ETALON-2, showing semitrain returns

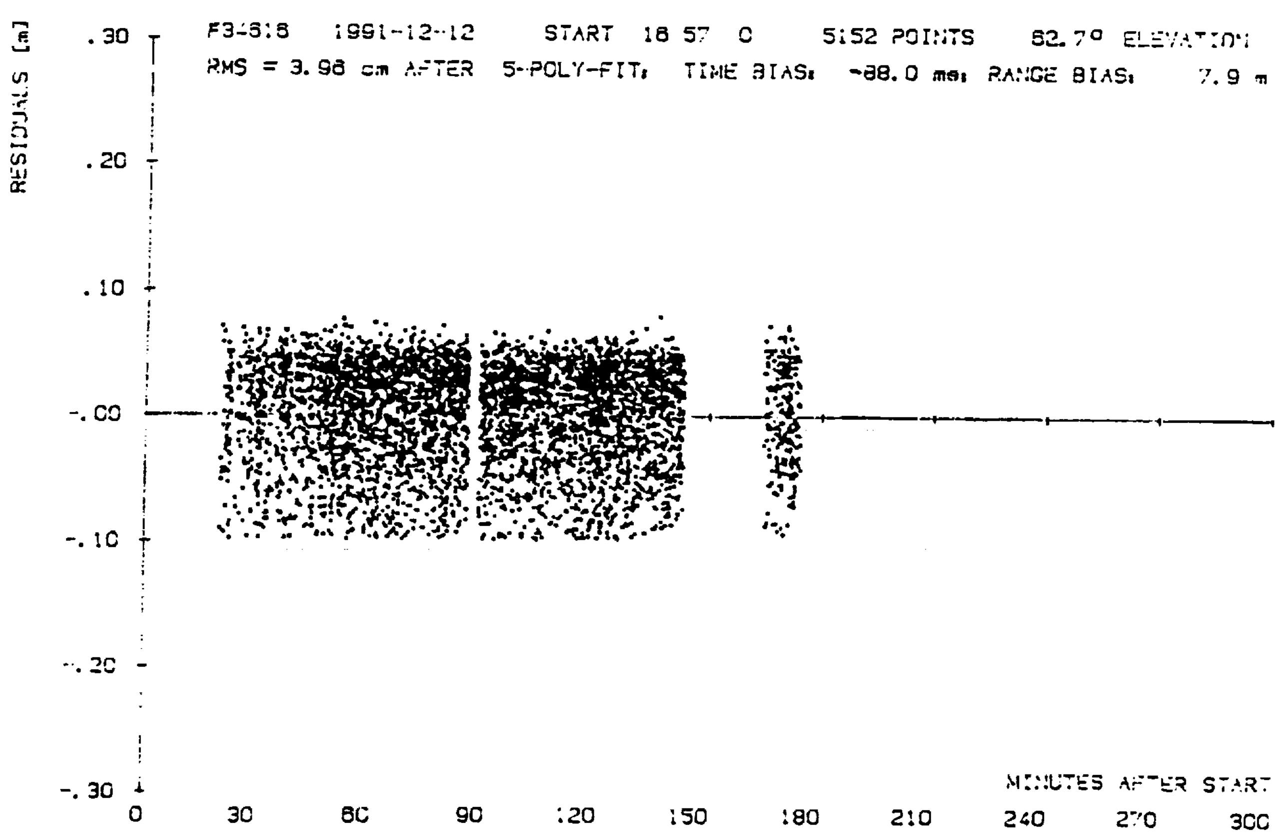

Figure 5: Same ETALON-2, with non-symmetric distribution