Millimeter Ranging Accuracy the Bottleneck

Ivan Prochazka, Karel Hamal

Czech Technical University in Prague
Brehova 7, 115 19 Prague, fax +420 221912252, prochazk@mbox.cesnet.cz

The ultimate goal of the satellite laser ranging is the millimeter precision and accuracy. The accuracy of the satellite laser ranging may be estimated on the basis of analysis of all the individual contributors to the ranging error budget [1]. All the error budget contributors have their random (precision) and systematic (bias) components. It means, that the correct understanding and interpretation of the ranging precision is the precondition of the ranging accuracy statement. In our paper we are demonstrating the fact, that the list of the satellite laser ranging error budget contributors in not complete. This is demonstrated on the discrepancy between the ranging precision achieved ranging to ground targets and to satellites. The best existing ground based ranging systems are capable to achieve millimeter ranging precision when ranging to short distance terrestrial targets. However, ranging to Earth orbiting satellites the best precision obtained is typically 3 times worse, about 3 millimeters RMS. As this value is obtained even for satellite targets not spreading in time the echo signal, there is was a speculation, that the remaining contribution to the random error budget is contributed by the atmospheric fluctuations. However, the current results of numerical modelling of these effects showed [2], that the atmospheric contribution to the satellite laser ranging precision is lower by two orders of magnitude.

As a conclusion: there exists an error in SLR, both random and systematic, which has not been identified till now. The random component of this error is on a millimeter level, its systematic component may be estimated once it will be identified and characterized. We would like to urge the SLR community to look for this error source.

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References

1. M.R.Pearlman, *System characterization parameters*, Proc. of the Workshop on Laser Ranging Instrumentation, Herstmonceux Castle, UK, 1984, edited by H.Seeger, IFAG,
2. I.Prochazka, L.Kral, *Atmospheric contribution to the satellite laser ranging jitter*, in this Proceedings

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Accuracy

- A measure of the closeness of a measurement /average/ to the true value.
- Includes a combination of random error (precision) and systematic error (bias) components.
- It is recommended to use the terms "precision" and "bias", rather than "accuracy," to convey the information usually associated with accuracy.
- *definition according to* USC Information Sciences Institute, Marina del Rey, CA (www)

Accuracy check

- Comparison to more accurate method

  For SLR accuracy check such a method is not available

- characterizing ALL individual error budget contributors, their precision and biases
  (M. Pearlman, System characterization parameters, Herstmonceux, 1984)

PROBLEM :
The list of our error budget contributors is not complete.

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SLRprecision discrepancy

Contributor	Precision
Ranging Machine (calibration)	1 mm
Atmosphere	0 mm
Satellite (sphere)	0 mm
r.s.s.	1 mm
Measured SLR (MLRO, Graz)	2 - 3 mm
Not identified contributors	~ 2 mm

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Goals

- Identification of ALL the error budget contributors
- Determining the precision and possible biases of all these components

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"New" SLR error budget contrib

- Laser wavefront
  - Most systems calibrate using a near field "sample" of the beam, however, SLR is based on a far field wavefront
- Reference frequency
  - RF and harmonic distorsion of the master frequency signal bias the timing
- Data processing
  - the "numerical noise" of SLR data processing
- SLR geometry
  - the satellite range is not one half of the pulse travel back and forth
- Timing devices linearity and biases
- (many ?) Others

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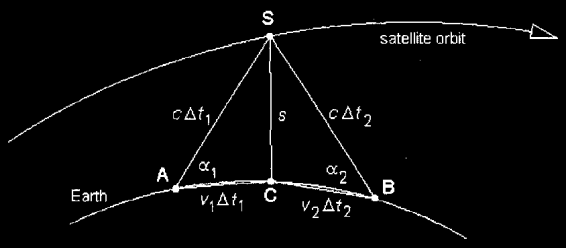
SLR geometry

- J.Kabelac, “Determination of reflection time”, Vermessung und Geoinformation, No.4,97Wien, Austria,1997,pp288-289



- Consequences
  1. The reflection time is not equal to the emission time plus 1/2 of propagation time.
  2. The satellite distance is not equal to 1/2 of the beam path length.
  3. The range discrepancy may reach 0.5 mm (!)

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Conclusion

- The discrepancy “Calibration x SLR” precision indicates that our error contributors list in not complete

  = > un-known SLR biases exist on millimeter level

- identification and characterization of these contributors is inevitable for further SLR accuracy improvement

  => long way to 1 mm SLR accuracy

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