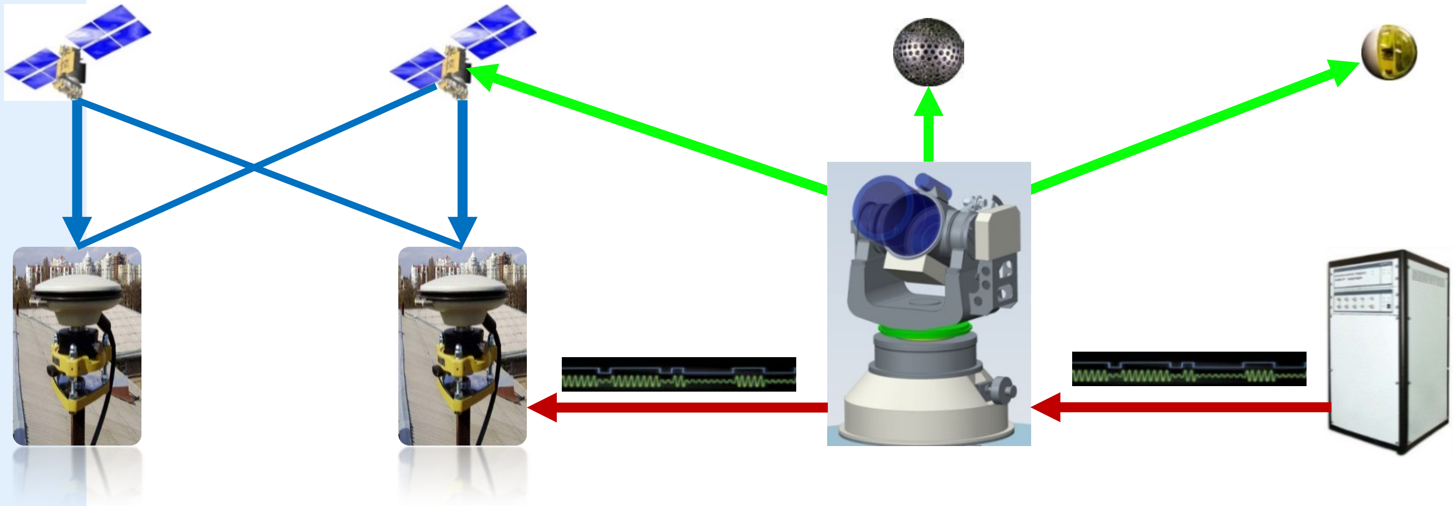
ILRS Technical Workshop 2015
Matera, Italy

SATELLITE RADIO LASER RANGING STATIONS FOR APPLICATION IN GNSS: REQUIREMENTS FOR THE TECHNICAL CHARACTERISTICS AND METHODS OF THEIR IMPLEMENTATION



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Agenda

1. Concept of radio laser measurements of navigation parameters;

2. Targets and tasks of radio laser measurements application in GNSS;

3. Technical requirements for performance rates of radio laser stations and methods of their implementation;

4. Technical requirements for measurement accuracy of radio laser stations and methods of their implementation;

5. Technical requirements for a normal point formation algorithm and methods of their implementation;

6. Technical requirements for operating modes of radio laser stations and methods of their implementation;

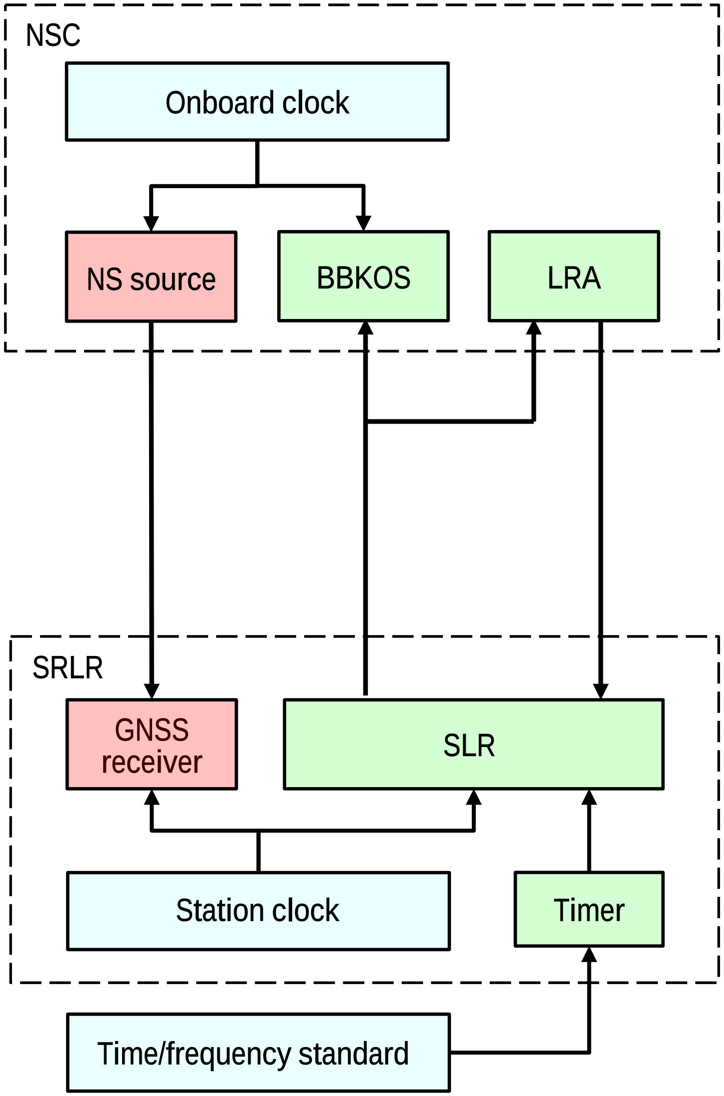
7. Conclusions.

Concept of radio laser measurements of navigation parameters

Radio laser station performs coordinated laser ranging, laser pseudoranging and radio pseudoranging by navigation signal code and phase

Coordination of measurements is provided by:
- the use of the common on-board and ground time scales;
- conjunction between the LRA reflection center and BBKOS optical center;
- conjunction between GNSS receiver phase center and station reference point;

The coordination of measurements allows us to compare estimations of range and on-board time scale divergence, as well as to evaluate hardware delays in navigation equipment and other parameters



Targets and tasks of radio laser measurements application in GNSS

GOAL

Verification and accuracy increase of GNSS geodetic and ephemeris-and-time support

TASKS ON ACCURACY INCREASE:

- **GNSS reference receivers and laser stations' geocentric coordinates determination;**
- **GNSS orbit parameters determination using laser or combined radio and laser measurements;**
- **laser time transfer between remote time and frequency standards;**
- **hardware delay calibration in on-board and ground navigation equipment;**

MEANS

- **SRLR stations taking coordinated laser ranging/pseudoranging and radio pseudoranging measurements;**
- **VLBI, SLR, GNSS and DORIS co-location nodes**

HOW TO USE LASER DATA

- **combined use of laser and radio measurements in order to increase accuracy of geodetic and ephemeris-and-time support;**
- **calibration of GNSS receivers with the use of laser measurements and further use of GNSS all-weather receivers for taking measurements on the calibrated parameters save interval;**
- **improvement of navigation SC orbital motion models (first of all, the radiation pressure and antenna phase centers shift models) based on laser measurements**

Technical requirements for performance rates of radio laser stations and methods of their implementation

CRITERIA

each station of the network must produce a normal point on every visible navigation SC every 15 minutes

↓

REQUIREMENTS FOR PERFORMANCE RATES

N = 576 NP/day = 24 NP/hour,
or
1 NP every 2.5 min

↓

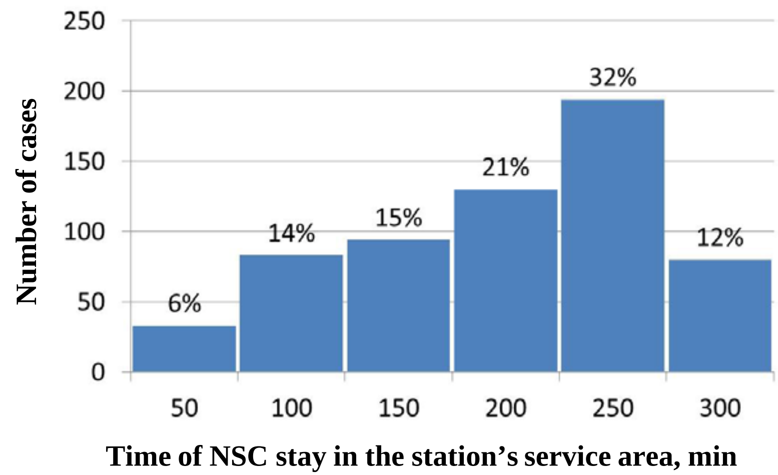
CONDITIONS TO PROVIDE SUCH PERFORMANCE RATES

1. An SLR station must take measurements both day and night;

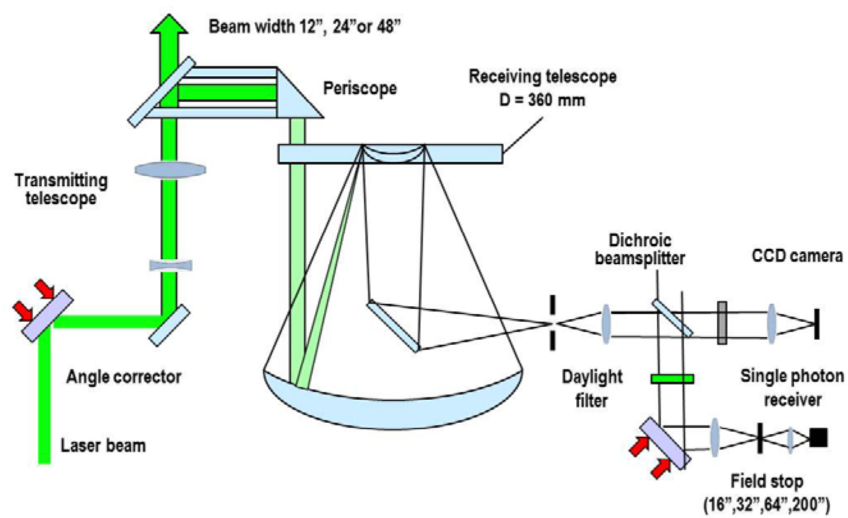
2. Time of re-targeting and locking on a SC for tracking must not exceed approximately 1.5 minutes;

3. Time of data collection for normal point formation must not exceed approximately 1 minute;

4. Calibration of a hardware correction to the laser station must be performed simultaneously with measurement data collection.



Implementation of daytime functioning and «blind» guidance in the «Tochka» laser station



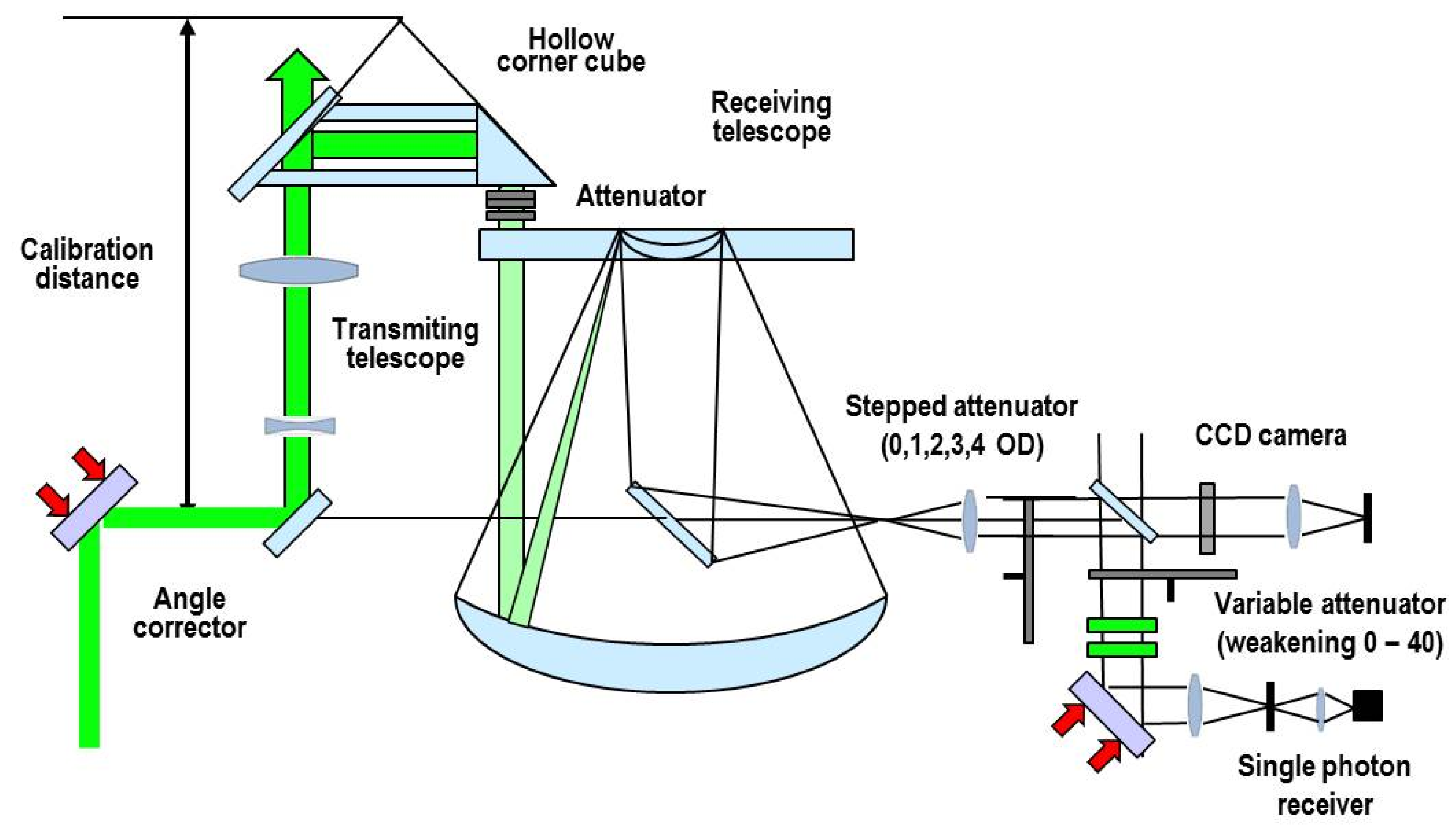
Technical requirements for measurement accuracy and methods of their implementation

Requirement	Solution
NP error random component must be less than 1 mm on the averaging interval of 1 min	1. Return impulse duration is less than 150 ps (s); 2. Data collection rate exceeds 30 Hz.

Requirement	Solution
NP error systematic component must be less than 1 mm on the averaging interval of 1 min	1. Single-electron receive mode; 2. Calibration must be done with an error of less than 1 mm during data collection.

Technical requirements for measurement accuracy and methods of their implementation

Implementation of single-electron receive mode and calibration in the «Tochka» station



Technical requirements for a normal point formation algorithm

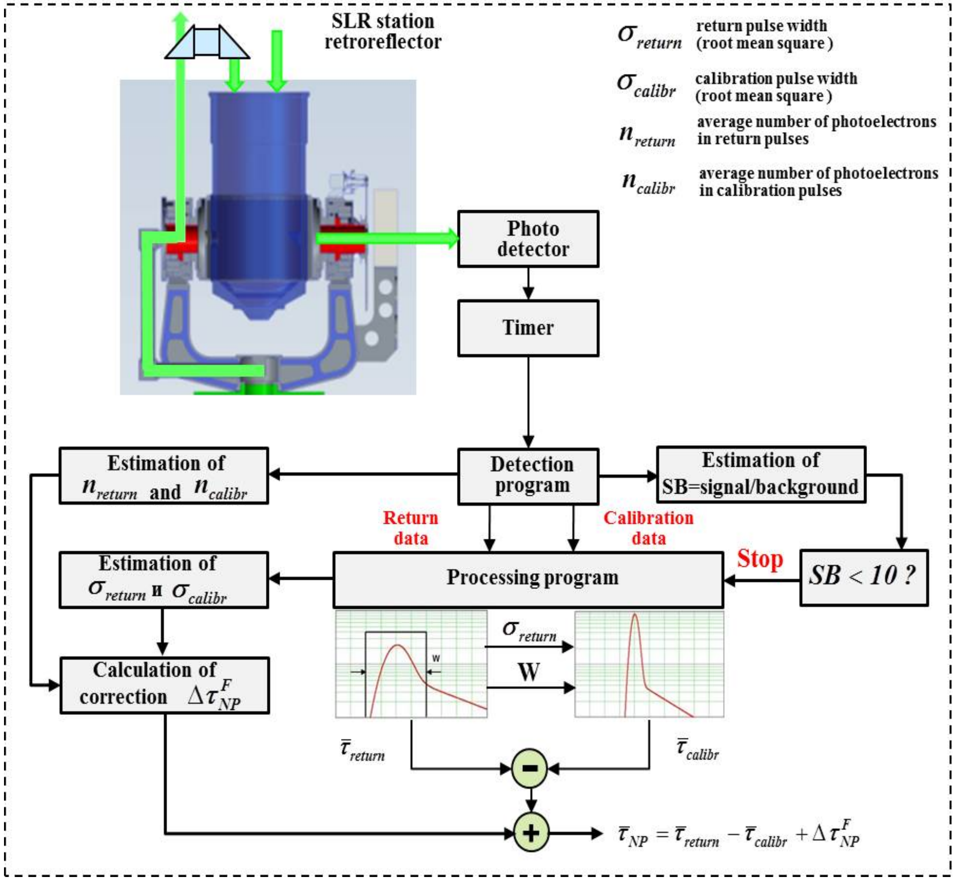
REQUIREMENT

Algorithm of NP formation must not introduce systematic errors to range estimations

SOLUTION

1. Algorithm must evaluate and consider the difference between return and calibration impulses with regard to their durations and average numbers of photoelectrons;
2. Algorithm must evaluate and consider impulse arrival time distribution upon filtration of measurement data;
3. Algorithm must evaluate a portion of measurements conditioned by the background and then stop processing upon having low signal/background ratios.

Implementation of the NP formation algorithm in the «Tochka» station



Technical requirements for operating modes and methods of their implementation

Probability of SC observation per day for the pessimistic scenario

№	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1	0.08	0.125	0.152	0.155	0.16	0.167	0.175	0.16	0.144	0.10	0.07	0.10	0.14
2	0.24	0.28	0.25	0.21	0.18	0.186	0.184	0.18	0.169	0.237	0.26	0.22	0.22
3	0.18	0.23	0.24	0.19	0.22	0.23	0.21	0.28	0.23	0.16	0.17	0.184	0.21

Probability of SC observation per day for the optimistic scenario

№	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1	0.2	0.32	0.39	0.4	0.42	0.43	0.45	0.42	0.37	0.26	0.17	0.25	0.36
2	0.42	0.5	0.45	0.37	0.32	0.33	0.33	0.32	0.3	0.42	0.47	0.48	0.39
3	0.41	0.53	0.55	0.43	0.50	0.52	0.47	0.64	0.52	0.37	0.39	0.42	0.48

Performance rate of a station doubles up provided that it functions through overcast breaks. To meet this requirement, the station must be equipped with a respective cloud cover detector, and a station control program must dynamically rebuild the observation schedule considering the current cloudiness status.

If applied in GNSS, the probabilities of observation tasks completion using laser means are insufficient.
Every navigation SC observation zone must be covered by three or four extra stations placed in locations with uncorrelated cloudiness statuses.

Conclusions

1. **The primary goal of SLR measurements application in GNSS are the tasks of verification and GNSS geodetic and ephemeris-and-time support accuracy increase.**

2. **To achieve the centimeter accuracy of orbits determination for navigation SC equipped with laser retro-reflectors, the performance rates of SLR station must be increased by more than 1 order at the expense of a data collection time reduction and automatic functioning under day conditions and through overcast breaks. In fact, we mean making SLR stations function in a 24/7 mode of operation.**

3. **We have technical solutions increasing the SLR station accuracy to 1 mm and its performance rate to 1 NP per 15 minutes on every NSC and also enabling permanent SLR application in GNSS.**

4. **Radio laser stations taking coordinated and parallel range and pseudorange measurements as applied to GNSS additionally enable laser monitoring of frequency-time parameters, mutual calibration of laser and radio measurements and precision time transfer regardless of weather conditions.**

Thank you for your attention! ☺