SLR for Low Orbit Satellite Observation

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Key words: SLR, LEO, Geoid, GRACE, GOCE.

ABSTRACT

The high accuracy model of geoid is very important for height determination by using GPS. Different techniques are used to acquire low orbit satellite orbiting measurements for this purpose. The ground based SLR observations are rather complicated for low orbit satellites CHAMP, GRACE and GOCE which will be used for geoid improvement. The satellite laser ranging system (SLR) for low orbit satellite observations is currently under development in Riga. The main objective of the development of a new project of SLR telescope mount together with its optical and mechanical components, electronics, computer software and GPS steered timing system is to design a mobile SLR of small size with a high capability to track fast-moving low orbit satellites including the zenith zone. The design of the SLR mount has allowed the minimum size and weight for a system which features a 35 cm primary mirror carried on an alt-alt mount, driven by stepper motors. The entire system, including the mount drive, angular encoders, laser firing control, gating control, rotating mirror control, range, time and meteorological information interfaces, as well as software including predictions, data processing, normal point computation, reporting, communications, etc., will be controlled by a single PC. The total weight of the system is expected less than 100 kg and it will be fixed in case and ready to move by almost any vehicle including small cars and light aircraft without dismantling the SLR.

KOPSAVILKUMS

Pielietojot GPS augstuma noteikšanai, ir ļoti svarīgi, lai būtu augstas precizitātes ģeoīda modelis. Zemo orbitu satelitu pozicijas mērījumu iegūšanai tiek lietota dažāda tehnika. Uz zemes bāzēto SLR zemo orbitu satelitu CHAMP, GRACE, GOCE novērojumi, kuri tiks pielietoti ģeoīda uzlabošanai, ir diezgan sarežģīti. Patreiz Rīgā tiek konstruēts zemo satelitu lāzernovērojumu tālmērs (SLR). Galvenais mērķis ir konstruēt jauna projekta SLR montāžu kopā ar tās optiski - mehāniskajām komponentēm, elektroniku, programmatūru un GPS sinhronizētu laika sistēmu, kas būtu kā mobila nelielu gabaritu SLR zemu orbitu satelitu novērojumiem ar iespējām novērot ātri pārvietojošos satelitus arī zenita zonā. Konstrukcija izdevusies kā minimāla lieluma viegla SLR montāža ar 35cm galveno spoguli, nostiprinātu uz alt-alt montāžas, kuru vada soļu motori. Visas sistēmas vadību nodrošinās viens PC, tai skaitā montāžas motoru, leņķu devēju, lāzera aizdedzes sistēmas, laika vārtu, rotējošā spoguļa vadību, attāluma mērīšanas, laika un meteo informācijas saskarni, kā arī programatūru satelitu kustības prognozēšanai, datu apstrādei, normālpunktu aprēķiniem, atskaites ziņojumu

sastādīšanai, sakariem u.c. Sagaidāms, ka kopējais sistēmas svars būs mazāks par 100 kg, tā būs nostiprināta kastē, kuru var pārvietot jebkurā laikā ar nelielu auto vai lidmašīnu.

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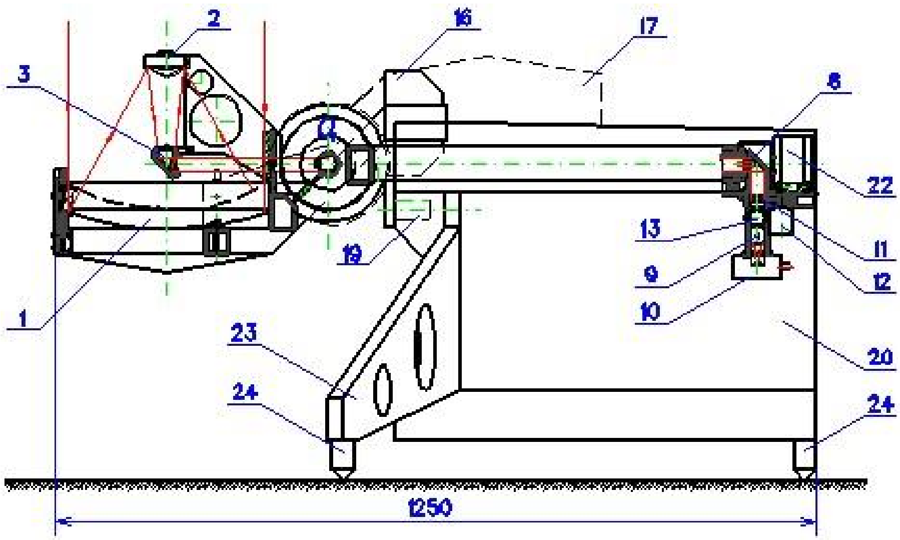
1. INTRODUCTION

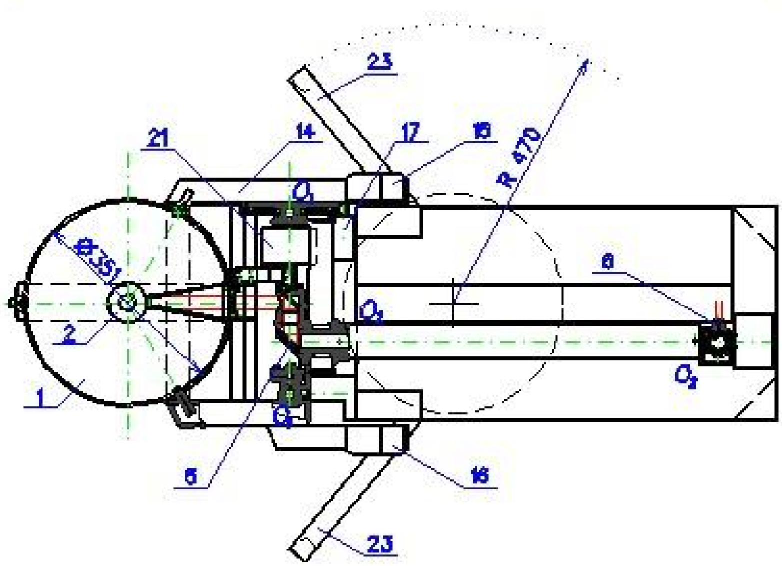
Low orbit satellites are launched more and more for different tasks of the Earth exploration, see Dickey (2000), Shum et al. (2000). The SLR observations still are important for satellite orbit determination in spite of the fact that such powerfull systems as GPS, DORIS, TRANET and PRARE are used for satellite tracking widely. Satellite Laser Ranging provides the most accurate and least ambiguous of all measurements used to track near-Earth satellites, see Klosko (1998). There are fully automated NASA SLR2000 under development now and it is expected that the best results will be achieved, see Degnan (1998). There are many other highly efficient SLR in operation, for example SLR in Yarragadee, Potsdam, Matera, Wettzell, Riga (LS-105), Keystone, TIGO, and many others. However, for the low orbit satellite observations there are different difficulties, see Baustert, Koenig (1998).

GFZ-1 has demonstrated the possibilities and difficulties of tracking such low targets with state-of-the-art SLR systems (Chen and Koenig 1996). Since its start GFZ-1 has orbited nearly 24,000 times around the Earth. During 4 years and 64 days in space, 5,402 passes of GFZ-1 were observed by 33 stations of the global SLR network, see Reigber and Koenig (2000). Currently in the orbit is improved satellite CHAMP and the SLR observation reports demonstrate that observations of this satellite are rather difficult. Very soon will come launch of GRACE satellite of the same category, in the year 2005 is planned the launch of GOCE. The new satellite gravity missions (CHAMP, GRACE and GOCE) will bring substantial improvements to our knowledge of the gravity field and thereby of the (quasi-) geoid, see Tscherning et al.(2001). The geoid will be determined to within 1 cm at wavelength down to 100 km. All these satellites will have onboard GPS. However, till now the SLR observations are still important. They are very important also for altimeter calibration for the satellites JASON, ENVISAT, ICESAT, etc. The number of Earth exploring low Earth orbit (LEO) satellites with laser reflectors are still growing and we hope that the new SLR designed in Riga will be usefull. The experience of the PSLR achievements and faults will help very much (Abele et all. 1996).

2. TELESCOPE MOUNT

The main optical system is assembled on a gimbal (14), rotating around axis O_1-O_1 by 270^o by means of motor (15). In the initial position (17) the frame of the main mirror covers the mount body. The bearings of this axis are fixed in the second gimbal (18), mounted on horizontal axis O_2-O_2., which can rotate by 180^o, driven by motor (19). In order to decrease motor load, the gimbal (14) is balanced against both axes using counterweights (16). Position of axes are monitored by encoders (21) and (22). The bearings of the horizontal axis are fixed in the body (20), also laser transmitter (7), its control electronics and cooling system are accommodated there. The body is supported by 3 adjustable feet (24), two of which are on the levers (23).In transport position levers are fitted to the body.





3. OPTICAL SYSTEM

The main optical system consists of the main mirror (1) and secondary mirror (2), arranged as in Mangen system, where the reflective coat covers the back of glass and is well-protected against corruption. The converging beam from the secondary mirror is made parallel by the lens (3), fastened to the prism. Mirrors (4) and (5) conveys the parallel beam through the horizontal axis O_2-O_2.

The incoming beam from the laser (7) is fed into the optical system by a small prism (6). After passing through the optical system, it is collimated to a part of the main mirror.

CONTROL ELECTRONICS

Instruments and devices, supporting SLR functionality, will be controlled by a set (2 or 3) of IBM PC hosted custom extension PCBs. Besides interfacing PC to external devices, control electronics will perform a number of data interpretation and real-time functions. The functionality of control electronics include:

- Support of system time scale, driven by external 10 MHz and 1 pps reference signals (obtained from a GPS time receiver or other time standard). Most control events are synchronised with system time and event time moments are fixed relative to system time (with 100 or 20 nsec accuracy).

- Generation of control cycles. Each control cycle includes a synchronised hardware interrupt, associated interrupt handler performs all time-critical software tasks and allows to synchronise control software and hardware. Duration of control cycles may be 1 msec or more (in 2 mksec steps).

- Generation of stepper motor control pulses (steps) according to control software request. Exactly the requested number of steps for the requested time interval (one control cycle) is generated. Step timing is synchronised to the system time scale with at least 1.8 mksec accuracy.

- Processing of TTL square-wave pulse trains from incremental angle encoders. Upon request control software can obtain encoder pulse counts (relative mount position) for the start moment of the current control cycle.

- Timing of external events (such as laser pulse, encoder and rotating shutter calibration marks) with 100 or 20 nsec accuracy.

- Generation of triggering and gating signals (laser start, time gate) according to control software request.

- Control of additional stepper motors (rotating shutter).

- Mount joystick, end-switch and automation signal interface.

Additional standard extension PCBs (IEEE488 adaptor, CCD adaptor) may be necessary.

CONTROL SOFTWARE

SLR mount and all involved devices will be controlled by a single PC with MS Windows 9x, XP or NT 4 operating system (the only custom requirement is sufficient number of extension slots and space for extension PCB's) . The control software will use MS Windows API based interface. Our intention is to make the control system as user-friendly, easy to use and automatic, as possible. However, we recognize, that fully automatic LEO satellite observations are hardly possible.

The main control cycle is driven by clock-synchronised hardware interrupts; an interrupt handler performs all time-critical tasks, allowing other software components to run asynchronously.

The software will support following functionality:

- Mount referencing (utilising encoder reference pulses), moving to static position, tracking dynamic targets (target position predictions in form of a set of approximating polynomials); joystick (or it's emulation from keyboard or mouse pointer) corrections to predicted mount position.

- CCD image processing, allowing automatic tracking of an object. Possibly, an extra image monitoring PC may be needed.

- Mount offset and mount error model determination. Reference stars (using FK5 or other catalogue) or static reference target observations are used for this purpose. Optimal mount error model structure will be developed when mount prototype will be available.

- Calibration target ranging. Simultaneous calibration is possible if a separate gating pulse for calibration is provided. Graphic representation of results in real time including some editing and gate/window control facilities.

- Satellite ranging. Graphic representation of results as above, satellite prediction time bias can be calculated and applied in real time.

- Satellite predictions calculation facility, based on an IRV integrator. Predictions can be calculated immediately before pass or in advance and retrieved from a file on request. Graphical representation of satellite passes (as sky plots or geographical maps).

- Processing of calibration and satellite ranging results, including graphical data editor, polynomial approximation of O-C values, time and range bias estimation, normal point generation and data export to external exchange formats.

- Satellites, sites, IRV, hardware configuration, observations, calibration, meteo and tracking control databases

– Meteo subsystem, allowing to retrieve and record temperature, humidity and pressure.

– Rotating shutter control facility.

– Interface to time interval counter.

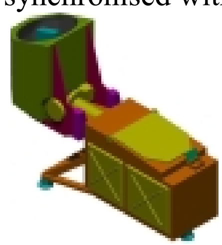
– Interface to a GPS receiver.

– Timing system synchronisation facility.

– Interface to PC and mount joysticks, end switches, some other control signals.

– Online help facility.

Interface to measuring devices (meteo data, time interval counter, GPS) will be implemented via standard RS232, IEEE488 or USB adaptors. Communications to time interval counter, CCD sensor and meteo subsystem are synchronised with the control cycle and do not overlay.



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