ARTICLE IN PRESS
NRIAG Journal of Astronomy and Geophysics (2015) **xxx**, xxx–xxx

National Research Institute of Astronomy and Geophysics
NRIAG Journal of Astronomy and Geophysics
www.elsevier.com/locate/nrjag

Satellite Laser Ranging in Egypt

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Received 14 January 2015; revised 13 May 2015; accepted 2 June 2015

KEYWORDS

SLR;
Full-automatic station;
Equipments of SLR-stations;
Data analysis

Abstract The paper concerns on the satellite laser ranging (SLR) in Egypt. The three generations which can be loosely defined by their single shot root mean square precision, are discussed. The laser generators used at the Helwan half automatic and full automatic stations are described. The equipments used for the operation of the satellite laser ranging and their upgrading are presented. The observations carried out from Helwan-SLR stations are mentioned. The importance of the satellite laser ranging from Egypt and their contributions to the SLR network are explained. The modification requested for increasing the performance of the Helwan-SLR station is given.

1. Introduction

This paper deals with the satellite laser ranging in Egypt. By the way, there is a celebration by the passing of 50 years of the SLR. This celebration is carried out at the Maryland, USA, during the 19th International Laser Ranging workshop. The ground stations of the SLR network consist of about 50 stations observing artificial satellites and the lunar retroreflectors. Almost all SLR stations are unique and developed in an individual way, therefore, operating different devices installed and managed by different software. The SLR station consists of high energy ultra-short pulsed laser, precise timer, and optionally ultra-stable clocks, photo detector, narrowband filters, and well-mounted telescope (Pearlman, 1981).

As development that progressed laser tracking systems have been categorized into three generations which can be loosely defined by their single shot root mean square (RMS) precisions. The RMS of the first generation is greater than 50 cm, as for the second generation, between 10 and 50 cm and in the third generation, the RMS is better than 10 cm. Differences in instrumentation and approach that also differentiate between the three generations are discussed. Tracking systems in all these categories are still operational in various parts of the world, but many are in the process of upgrading to the 3rd generation specifications, in order to meet the stringent precision requirements being set by current geodynamic and geophysical applications. In this paper, we explain the situation of the three generations of the SLR in Egypt. A brief description of the used laser generators used at the Helwan SLR stations is also given. The atmospheric correction and the system delay are computed from the Helwan SLR station site. The expected upgrading of the station in order to increase its performance is explained.

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Peer review under responsibility of National Research Institute of Astronomy and Geophysics.

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http://dx.doi.org/10.1016/j.nrjag.2015.06.002
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Please cite this article in press as: Ibrahim, M. et al., Satellite Laser Ranging in Egypt. NRIAG Journal of Astronomy and Geophysics (2015), http://dx.doi.org/10.1016/j.nrjag.2015.06.002

2. The method used for the satellite laser ranging

The satellite laser ranging (SLR) is an accurate method for satellite tracking. Fig. 1 is a simplified block diagram that shows the principle measurement of the satellite laser ranging. A portion of the outgoing laser pulse is detected by the photodiode, which starts with the time of flight measurements. The remainder of the pulse propagates through the atmosphere to the satellite, where it is reflected by the retro-reflectors back to the receiving telescope.

The telescope collects and focuses the returning laser pulse on a photomultiplier, and the resulting signal stops the time of flight measurements. The computer with the epoch time of the measurements and other supporting information stores a digital word representing the round trip time of flight. The system delay is computed and removed from the time of flight measurements (Pearlman, 1984).

The modeling of error sources and the calibration of biases from laser ranging systems (Tapley et al., 1982) may be written, to allow for possible error sources, as

$$R = c(\Delta t/2) + \eta_r + \eta_e + b + \varepsilon \quad (1)$$

where R is the range from the laser reference point to the average satellite retro-reflector position, c is the speed of light in a vacuum, and Δt is the time of flight. η_r, is the atmospheric refraction correction (as explained in Section 2.1), η_e is the effect of the systematic and random measurement error (as explained in Section 2.2), b is the system delay as determined by calibration measurement (as explained in Section 2.3), and ε is the un-modeled observation error (Tapley et al., 1982). This is the procedure adopted by most centers currently processing laser ranging observations.

2.1. The atmospheric correction (η_r) as measured from Helwan-SLR station

The simple atmospheric correction calculation is ideal for SLR stations as it only requires local atmospheric measurements to be taken at the ranging site. As a laser pulse propagates through the atmosphere, it experiences a delay due to the troposphere refraction. This has the effect of an increase in the apparent range to the satellite, which varies between nearly 13.5 m at an elevation angle of 10° and 2.4 m at 90° (Sinclair, 1982). Generally, local safety regulations prohibit tracking below 20° at most SLR sites. Since most stations do not range below 20°, as attenuation below this elevation reduces signal intensity significantly, the Marini–Murray model is useful (Marini and Murray, 1973). For the purpose of the computation of the correction in the range of the satellite, the model is applied at the same meteorological condition during the observation of the satellite GFO-1 observed at February 8, 2005 (as an example), and the results are shown in Fig. 2. λ is the wavelength of the used laser, R_H is the relative humidity, P_0 is the atmospheric pressure and T is the temperature, each of them is measured at the station site. By the way, φ and HH are the latitude of the station and its height above mean sea level respectively. It found that, the range correction is about 2.43 m at an elevation angle 90° and increases to nearly 7.05 m at the elevation angle of 20°. As for the Helwan SLR-station, where the minimum elevation angle is 26°, the range correction increases to 5.52 m.

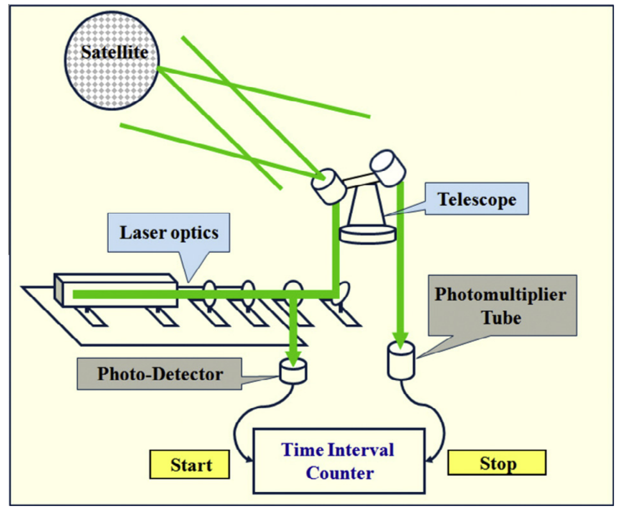

Figure 1 Block diagram of SLR technique.

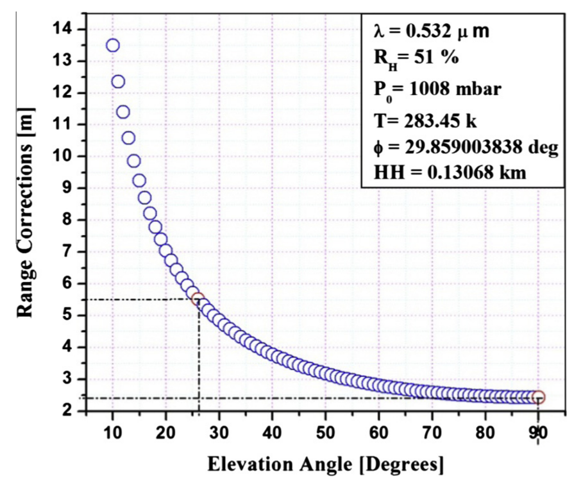

Figure 2 Range correction versus elevation angle as computed from Helwan-SLR station.

2.2. The center of mass correction (η_e)

For all laser ranging satellites the array of corner-cubes, which reflect the transmitted laser signal back to the tracking station, is displaced from the center-of-mass of the spacecraft (Otsubo et al., 1999). Furthermore, the orbit determination is referred to this reference point and so the observed ranges must be corrected accordingly. However, the pulse is not reflected from a single point but is a combination of reflections from all the reflectors facing the station. For spherical satellites (such as Lageos and Starlette) this correction is a simple constant offset and has been determined analytically (Fitzmaurice et al., 1978; Arnold, 1978) and by pre-launched calibration (Fitzmaurice et al., 1978). However, for other satellite the position of the reflector array must be considered, resulting in more complex correction formulae.