Acta Astronautica 117 (2015) 332–337

Contents lists available at ScienceDirect

Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

Single-satellite global positioning system

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ARTICLE INFO

Article history:
Received 1 June 2015
Received in revised form
3 September 2015
Accepted 5 September 2015
Available online 14 September 2015

Keywords:
Global positioning system
Interferometer
Satellite

ABSTRACT

A new concept of a global positioning support system, based on only one satellite, was offered. Unlike all other GPS and GLONASS satellite systems that are in use, within the offered modification, all metrological support is provided by on-board measurements, which means, that it does not need any ground support of coordinate measurements or orbital characteristics of the satellite system. The cosmic-based angle-measuring instrument measures the arcs lengths between the measured ground-points, that are marked with light beacons, and navigation stars. Each measurement takes approximately 0.04 s, with the precision of 1 mm in recalculation to ground-relations. Long series of arc measurements between different objects on the ground and in the sky enable the solution of both determination of geodesic coordinates of the measured points and position of the spacecraft during the measuring process by using geodesic equation methods. In addition, it enables the qualification of the geopotential guaranties. The offered scheme will be used for the determination of the frame of selenocentric coordinates during the "Luna-Globe" and "Luna-Resource" missions for precise navigation of landing modules and maybe will be used for precise gridding of the Martian surface.

1. Global positioning system

The determination of precise geodesic coordinates in a unified Earth-wide coordinate system is an urgent scientific challenge, which has a clear practical use. Currently for most of those practical challenges, this problem can be successfully solved by using multi-satellite global positioning systems like GPS, GLONASS and others [1]. With their help it is possible to receive coordinates of the receiver with the precision of single meters within a few seconds with household receivers and bring up the precision of the measured coordinates up to a millimeter level by using special receivers and many month long measurements. The efficiency of the global positioning satellite-groupment is supported by permanent orbital parameters measurements of each satellite within the groupment and it requires precise determination of the spatial position of the satellite, comparable to the precision of ground coordinate measurements. This is achieved through holding optical observations of the satellite-groupment from the ground, both goniometrical and distance measuring by using laser-location and a few dozen vantage points. Besides that, stable work of global navigation systems is permanently controlled through determination of their coordinates by numerous ground-stations, equipped with the most

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http://dx.doi.org/10.1016/j.actaastro.2015.09.003
0094-5765/

accurate equipment. Similar ground-obse;rvations have a naturally constrained measurement-precision of the spacecraft-position; therefore, all existing global positioning systems have a fundamental precision-limitation of the geodesic coordinates, measured by them. Even in best astroclimatic conditions the inhomogeneity of the earth-atmosphere leads to deviation of the visual ray to approximately 1…2 arcs. At a distance of 2000 km the measuring-error of the angular position of the satellite of 1arc matches an uncertainty of 10 m. Therefore, the measurement-precision of the satellite-position, necessary for correct operation of the global positioning system is achieved through averaging of a big number of measurements from dozens of ground vantage points and permanent control of the whole system according to the results of the coordinate-measurements from the supporting ground stations network. Currently the positioning-precision of cosmic navigation systems is almost reaching its limits. The most accurate coordinates are received from astronomic observations of stars. Astronomic observations and reliable time support of ground-observation enable the location-calculation of astronomic points at a very high precision, but all of them are determined within an individual "equipment" coordinate system of every instrument in the observatory, which brings systematic errors which are extremely difficult to consider and fend away. So even formally high precision of the held measurements do not justify high precision of the generalized "frame" system of geodesic coordinates [2]. Taking this short review into consideration, we should make an unambiguous conclusion: It is not possible to increase the precision of positioning to more than a few centimeters by using astronomic observation of orbs. However this limit is possible to overcome.

2. Ground positioning according to measurements from space

In the year 2001 it was offered to establish the whole geodesic coordinate system based on a single space-based measuring instrument [3]. This option actually eliminates the appearance of systematic "instrumental" errors and allows holding position-measurements of ground-based points, equivalent in their precision to astronomic observations, but without the installation of astronomic instruments into them. By placing a spot-light source (a light beacon for example [4]) at the measuring point on earth, the cosmic goniometer will be able to measure the angle "beacon-spacecraft-star", which is additional to the angle "star-beacon-spacecraft" (Fig. 1). By holding a series of observations of the beacon in relation to a few stars and knowing the spatial position of the spacecraft in relation to the earth mass-center coordinate system at the moment of the measurement, it is possible to calculate the geodesic coordinates of the beacon.

The precision of the angular measurements according to the offered scheme will be limited by the equipment-precision of the measuring-device and the angular size of the light beacon seen from it. By using semiconductor laser diodes with the physical size of the radiating body of 2 mm as the beacons light-emitter, the position of the

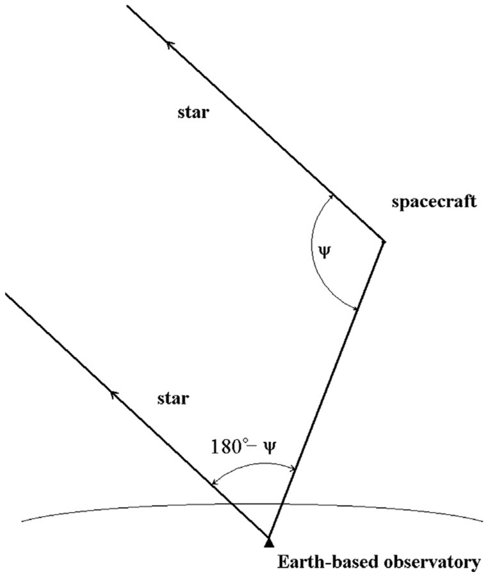

Fig. 1. Angilar measurement from space are equivalent to the observations from Earth.

luminescence-center can be measured with a precision of 0.2 mm. In other words, a laser light beacon is able to provide the fixation of its center on the ground surface with a sub-millimeter precision. Another advantage of a space-based goniometer for ground observations is that the turbulent layer of the earth atmosphere, in which the visual ray blurs into several arc seconds, is ground-related. In night-conditions the blurring angle of the ray reaches 1…6″ (during the day it can reach up to 8…10″). The height of the turbulent layer above the ground surface at night rarely exceeds 100 m, and during the day in strong updraft conditions can reach up to 1000 m. During the observation from space, the deviation of the visual ray is caused only by this ground-related layer. At such distances it blurs the size of the beacon, visible from the spacecraft up to several millimeters, but the position of the luminescence-center remains unchanged and it can be fixed with a sub-millimeter precision (Fig. 2).

The method of global positioning using a space-based goniometer is illustrated by Fig. 3. The geodesic coordinates of every point are being determined by three values $\{\varphi, \lambda, R\}$, i.e. latitude, longitude and height of the point (above the mass-center of Earth or the standard geoid – depending on the coordinate system). During the measurements from board of the spacecraft only one parameter is being determined – the angle between the two sources. The measured angle (for the fixation of the beacons location) depends on the coordinates of the ground source – those are three unknown values $\{\varphi, \lambda, R\}$, and on the location of the star, the coordinates of which $\{\alpha, \delta\}$ are known. The angle between two ground-based points (independently of the distance between them) does not depend on the values themselves $\{\varphi, \lambda, R\}$, but on the difference between the corresponding parameters for those points. This follows from the arbitrariness of the beginning of any spherical coordinate system. In geodesy the beginning of the coordinate system is the point of the